The Blast Furnace and Steel Plant

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The Blast Furnace and Steel Plant

Vol. X PITTSBURGH, PA., MAY, 1922 No. 5

Industrial Possibilities of South Will be Revealed at Meeting of Engineers

Spring Meeting of the American Society of Mechanical Engineers to Be Held in Atlanta May 8-11—Steel Mills and Foundries to Be Inspected in Birmingham, and Muscle Shoals Will Be Visited.

THE industrial resources and possibilities of the South are not generally understood. It is exceptionally fortunate, therefore, that the 1922 A. S. M. E. Spring Meeting is to be held in Atlanta, with excursions to other Southern cities, offering an excellent opportunity for the members of the Society to study at first hand the resources and meet the engineers and manufacturers of this section. In its future growth, the South will need the engineer and especially the mechanical engineer, the servant and master of industry. It can be confidently asserted, therefore, that as the industries grow, so will the strength and activity of the South increase.

In 1920 the South manufactured about one-sixth of the products of the United States. It had nearly one-half of the active cotton spindles and three-sevenths of the active cotton looms of the country and it used five-eighths of the cotton fabricated. About one-ninth of the pig iron of the country was manufactured in the South. One-third of the corn, over one-fifth of the wheat and about one-seventh of the oats were produced in the southern states. One-fourth of the coal of the country and about one-tenth of the iron came from south of the Mason-Dixon Line.

These figures indicate that already the South occupies an important industrial position, but studying recently published statements of resources we find that the future is even more encouraging. All of the bauxite, turpentine, sulphur and phosphate rock of the country is located in the South. They also have 60 per cent of the country's natural gas, 57 per cent of the petroleum, 50 per cent of the lumber, 45 per cent of the lead, 26 per cent of the coal and 10 per cent of the country's iron ore.

In view of the above facts we feel that the A. S. M. E. made a very wise selection in choosing Atlanta as its meeting place, and from the technical program outlined the meeting should be a very valuable one to attend. Seven of the sessions have been planned by the Professional Divisions of the Society and the strength of these new organizations is well shown in the fine programs that have been prepared. The mornings will be given over to the technical sessions, which will start at 9:30 a. m.

Many interesting inspection trips have been arranged for the visitors. While in Atlanta the plant of the Atlantic Steel Company, which is described in another section of this issue will be inspected.

The visit to Birmingham will be made on May 12, the day following the Atlanta meeting, and the party will go to Birmingham by sleeper from Atlanta. Headquarters have been arranged for at the Hotel Tutwiler, from which the inspection parties will leave at 9:30. Visitors may select between a visit to the foundry of the American Cast Iron Pipe Co. or to the by-product coke ovens of the Sloss-Sheffield Co. Both parties will meet at the Ensley plant of the Tennessee Coal, Iron and Railroad Co., where the blast furnaces, open-hearth furnaces, blooming mills, rail mills and power house will be inspected. Lunch will be served in this plant. Leaving the Ensley plant, the guests will be taken to the Fairfield plant of the T. C. I. & R. R. Co., where they will have the opportunity to inspect an entirely electrically driven plate and structural mill. This plant is also used for the manufacture of railroad cars, both of steel and wood. In the evening there will be a dinner at the Hotel Tutwiler.

Special accommodations have been arranged to visit Muscle Shoals on May 13th.

In view of the fact that so much attention has been drawn to the Southern steel plants by the holding of the spring meeting of the A. S. M. E. in Atlanta, we considered that it would be apropos to install a description of several of these plants in this issue. Accordingly a description of the plant of the Atlantic Steel Company of Atlanta will be found on page 252 and a description of the Alabama City plant of the Gulf States Steel Company on page 254. It is indeed interesting to note from these descriptions that the plants of the south are equal in every engineering respect with our finest northern plants.

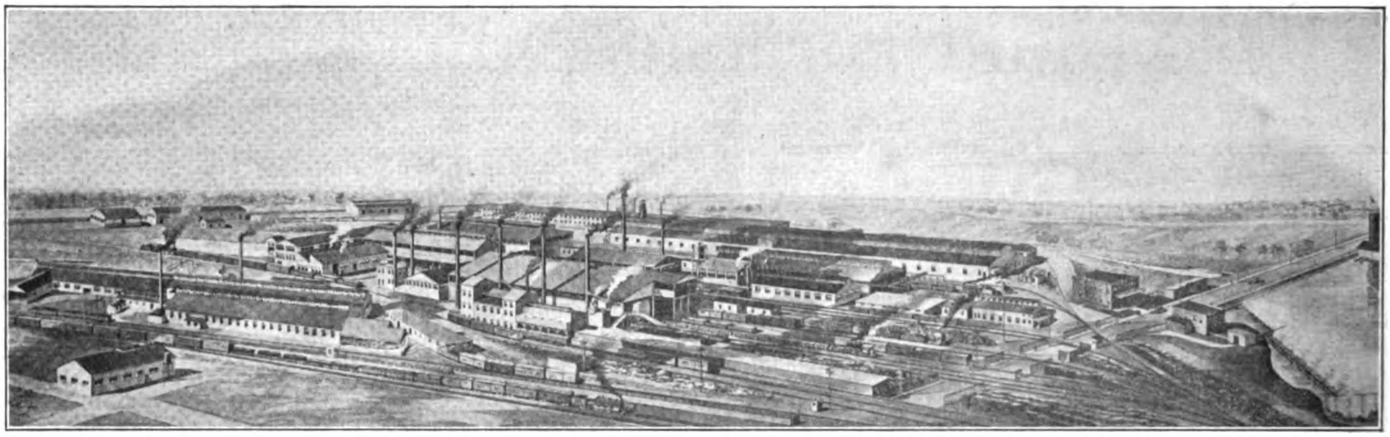

Fig. 1—Panorama view of Atlantic Steel Company, Atlanta, Ga.

Description of the Plant of the Atlantic Steel Company, Atlanta, Ga.

One of the Features of This Plant Is the Use of Powdered Coal for Firing One of the Open Hearth Furnaces and for Heating Purposes in the Soaking Pits—All Equipment Used of Modern Type.

THE Atlantic Steel Company is located just outside the city limits of Atlanta, Georgia, with local connections to all railroads leading out of the city. The well known shipping facilities of Atlanta is a distinct asset to the customer, shipments leave the yards within a few hours after receipt by the various railroads. In addition to the facilities of the city, the plant is equipped with every possible means of expediting an order. The warehouses have ample trackage while the yard has been laid out with the one end in view of prompt shipment. The plant transportation consists of locomotives, steam and electric cranes, conveyors, etc. The mills are located so that the raw material moves in one direction from start to finish, and orders for special material as well as standard stock are finished for shipment in the shortest possible time. Especial attention is given to packing export orders so that these reach the dock in record time. The products of the company commend themselves to the industries of the Southeast, especially to the cotton, turpentine and general agricultural interests. However, special orders within the capacity of the mill are handled with the greatest possible dispatch. In general the products are, rods in coils for rivets and for drawing wire, round and square bars in bundles, corrugated and twisted concrete reinforcing bars, heavy and light wagon tire, horseshoe stock, cotton ties and buckles, hoop steel for all purposes in coils or bundles. Nail wire, annealed black wire, galvanized wire, hog and cattle barbed wire, light and heavy, staples for barbed wire and poultry netting, field fence for poultry and live stock, common nails, flooring nails, roofing nails, slating nails, lathing nails, shingle nails, dowel pins, hoop fasteners, all of which receive the same scrupulous care in all processes of manufacture.

The steel made by the Atlantic Steel Company is melted in open hearth furnaces from pig iron and scrap. The proportion of the raw material depends, of course upon the quality of steel that is required. The three Morgan furnaces now in use are 38 ft. x 13 ft. x 7 ft. and have a maximum capacity of 60 tons per heat. Two of these furnaces are fired by gas from six Hughes gas producers 8 ft. 6 in. in diameter. The furnaces are of stationary reversing type with gas sewers 4 ft. 6 in. x 7 ft. 8 in. size, and stacks 5 x 130 ft. The third furnace is fired with pulverized coal. The coal for this furnace is dried to at least 1 per cent moisture content before pulverizing in a Fuller mill. The fineness is 96 per cent through a 100-mesh screens and 85 per cent through a 200-mesh screen. This pulverized coal, with a proper air mixture, is as inflammable as gas, and furnishes a better flame so that the time of melting in this furnace is as much as 30 per cent less than the time in a gas fired furnace. However, great care must be exercised in the selection of coal used, as a high sulphur coal will tend to make a high sulphur steel, but by proper care steel of equal quality may be secured.

The intensive heat of these furnaces, especially the direct coal fired furnace, necessitates an extensive system of water cooling of the furnace walls, doors and door frames, etc. The slag line on both the front and back walls is heavily piped as well as skewbacks and bullseye and an unusual feature is the piping in the uptake of the coal fired furnace, which adds extensively to the life of the furnace. The scrap, pig iron, limestone and refractories are hauled up an incline railway to the furnace floor level in standard W S M charging cars and pans. These are charged into the furnaces by a W S M 5-ton charging car which is an electrically operated floor track machine. During the charge the doors

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are raised and lowered by hydraulic pressure.

The melted steel when properly mixed is poured into a ladle of sufficient size to take the entire melt and from there poured into ingot molds which are set up on stools on permanent foundations. After they have sufficiently solidified the ingots are removed from the molds, usually by lifting the mold off the ingot, but in case the ingot sticks it is pushed out of the mold by an inclined hydraulic stripper of the Allen-Lang type. Each open hearth furnace has attached a Babcock & Wilcox three-pass double bank water tube waste heat boiler of 500 hp., equipped with a No. 6 Green fan running at 950 rpm. The reversing is made every 20 minutes by means of a 32-in. Forter valve, and a 42-in. mushroom air valve.

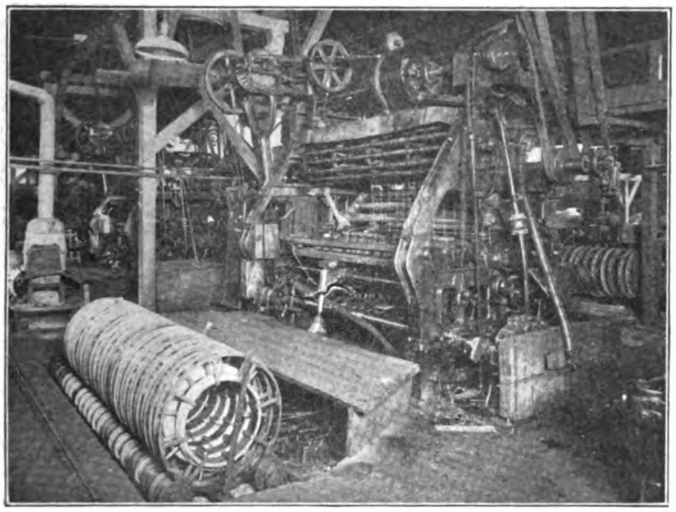

Fig. 2—View of field fence machine.

The soaking pits, which are eight in number, are fired with pulverized coal and are arranged in pairs with two pairs connected to a 4x90 ft. stack. These pits are 12 ft. 9 in. by 5 ft. by 9 in. deep. The cover doors are carried on a frame supported on wheels that roll on a horizontal track and when closed just clear the top of the pit walls. Part of the air furnished for combustion enters through a 12 in. pipe at 1½ lbs. of water pressure. The coal falls into this current of air and is carried into the combustion chamber by it. Additional air to complete combustion enters through openings in the wall of the combustion chamber. Control of the air, coal and cover doors is all from the pulpit just above the charging level running along the battery of pits. Each pit can be controlled separately from all the others and economy of operation kept uniform. The arch over the combustion chamber and the division walls are water cooled. Provision has been made for future utilization of the waste heat from these pits.

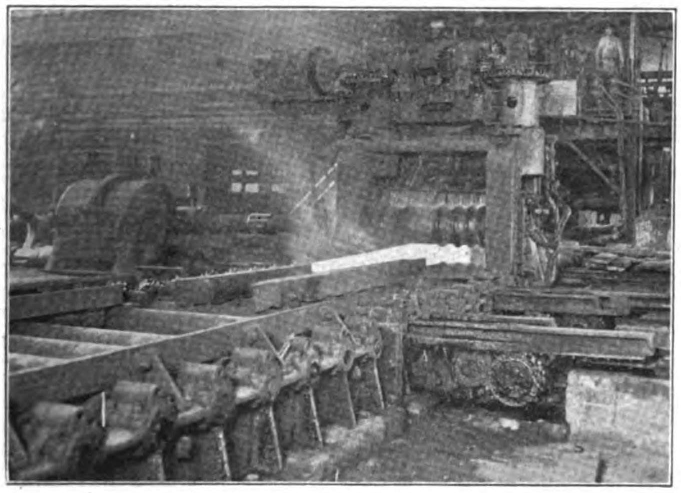

Fig. 3—View of blooming mill.

The ingots are brought to the soaking pits on a roller table, being weighed on scales in this table before charging. The charging and drawing is done by the same stiff legged crane. Two rows of ingots are placed on end in each pit so that the heat from the combustion chamber passes around each ingot. The heating process takes from three to four and one-half hours, depending on whether hot or cold ingots are charged.

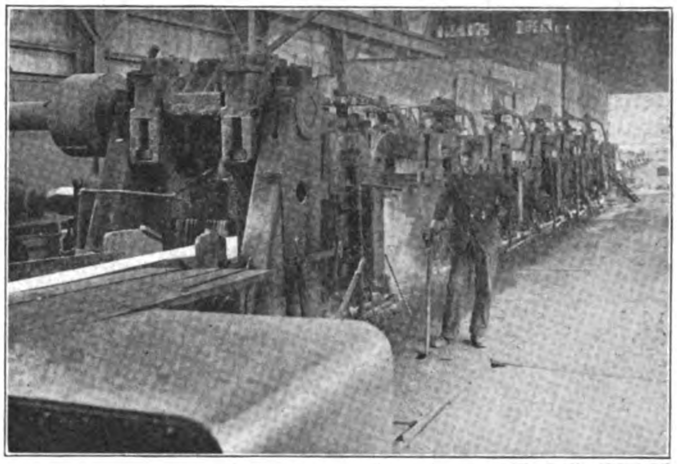

Fig. 4—View of continuous billet mill.

The blooming mill is 25x60 ft., made by the Mesta Machine Company, operated by a 2200 to 5000 hp. dc. Westinghouse reversing motor. Maximum speed 80 rpm. The ingots are reduced from 12x14 to 4x4 in 19 passes. The control is handled by three men in a cage above the roll table. Manipulator is operated hydraulically and the screw-down by motor. The Morgan continuous billet mill takes the 4x4 bloom and rolls it to a 1½-in. billet in six passes, 1¾ in. in five and 2 in. in four passes. These are cut into 30-ft. length billets by a flying shear and cooled on an 18-step cooling bed with capacity for 18,000 pounds. From the scales the billets are taken to the various finishing mills.

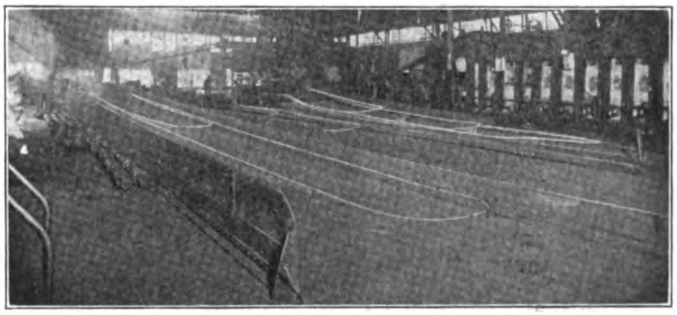

Fig. 5—View of rod mill rolling No. 5 rods.

The rod mill proper is a Morgan semi-continuous mill finishing a No. 5 rod in 14 passes from a 1½ billet weighing 7 lbs. to the foot. The continuous mill consists of six stands which delivers a 7/16-in. square. The other eight passes are handled by four men and two repeaters. The mill consists of the six-stand continuous mill two stands of 10-in. rolls, two stands of 9-in. rolls and two stands of 8½-in. rolls on four shafts, driven by a Corliss engine, at present 1800 hp., to be motorized in near future. The rod mill furnace is Morgan construction continuous type, built to take a 30-ft. billet. This furnace is gas fired, has three arches, the air for combustion is preheated by passing under sloping furnace bed. The billets enter at the upper end of incline and the pusher moves entire bed of billets down as each billet enters. The billets are pushed out directly into the continuous mill by a steam actuated clamp, belt driven pusher. The reels are belted from the engine while the conveyor is motor driven and speeded so that it takes five minutes to deliver a bundle of rods from the reels to the truck. The cooling bed for merchant bar holds 250-ft. pieces. The limits of the mill are 1⅜-in. round plain to ¼ in. on the cooling bed and ½ in. to No. 5 gauge rods in reels.

In addition to the above hot mill there are two hoop mills electrically driven and fired by coal direct. Capacity from 3x7/32 in. to ⅝ in. x No. 20 gauge, and a railroad spike mill with two automatic machines cutting ½ in. to ⅝ in. stock and a hand fed machine cutting 5/16 in. to 9/16 in. stock. The wire mills consist of a 50-block wire mill with cleaning tanks and baking ovens finishing wire from ½ in. to No. 18 gauge. Galvanizer capable of handling No. 2 gauge to No. 18 gauge. Barbed wire mill capable of making No. 12 gauge to No. 14 gauge wire, 4 in. to 6 in. spacing, two and four point and smooth twisted cable up to No. 10 gauge. Nail mill making all standard shapes of nails and spikes from 9 in. x 5/16 in. to ¾ in. x No. 17 gauge. Field fence, making field and poultry fences from 26 in. to 60 in. high.

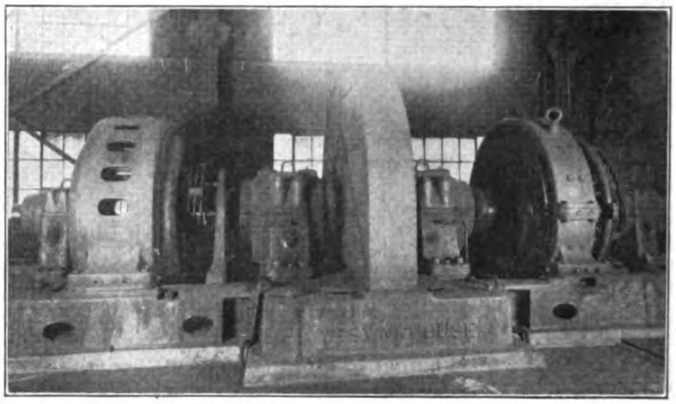

Fig. 6—View of rotary converter—blooming mill.

Description of the Alabama City Works of the Gulf States Steel Company

This Company Owns Plants and Properties Which Constitute an Integrated Steel Operation from Raw Materials and Fuel to Finished Product Consisting of Wire, Nails, Fencing and Bars.

THIS plant is located midway between Chattanooga, Tennessee and Birmingham, Alabama, at Alabama City, in a healthful, agricultural country. The climate is exceptionally moderate, making the labor conditions attractive.

The plant consists of the following units:

By-Product Coke Plant with Benzol recovery.
Blast Furnace.
Open Hearth.
Blooming Mill.
Merchant Bar Mill.
Rod Mill.
Commercial Wire Mill with various departments.

The plant is served by the Southern Railway, the Louisville & Nashville Railway and the N. C. & St. L. Railway.

The ground plan follows:

There are approximately 160 acres under fence with 80 acres adjoining held in reserve for future needs. Just outside of the plant inclosure are located 160 houses for employes together with large and complete Y. M. C. A. club house, commissary store, etc.

A description of the various units follows:

By-Product Coke Department:

This plant consists of one battery of 37, 12¼ ton, Koppers' cross regenerative by-product coke ovens. Capacity 500 cu. ft. which with crushed coal averaging approximately 55 pounds per cu. ft. gives an average charge of 13½ tons per oven. The oven chambers are 37 ft. long, 9 ft. 10 in. high and have an average width of 18¼ in.

The oven machinery consists of one Wellman-Seaver-Morgan combination pusher and leveler and door lifting machine. A standard type coal charging larry car operated by one D. W. Crocker-Wheeler 25 hp motor with hand operated standpipe swabbing machine, conveys the coal from a 700-ton bunker, across a standard railroad track scale, where each charge is carefully weighed. A 20-ton General Electric Company mining type locomotive with two quenching cars receive the coke from the ovens and take to quenching station. After being quenched the coke is dumped on to a Robins inclined wharf. From this the coke is fed by a rotary feed onto a 42 in. rubber, canvas conveyor belt, which delivers the coke to a 36 in. incline conveyor, then across a bar "grizzly" where the braize is screened out, the remaining coke being loaded into cars for the blast furnace.

The coal is received from the company's mines in dump cars, which are unloaded at a track hopper from which it is delivered by the usual shaker pans and pan conveyor to a 30 in. conveyor and thence to a revolving Pennsylvania Crusher Company Bradford breaker or cleaner where refuse coal is separated. The cleaned coal passes into two so called "mixing bins," capacity 200 tons each, and from there to mixing conveyors and into the Pennsylvania Crusher Company's hammer mill where a coal fineness of approximately 80 per cent through 1/8 in. mesh screen is maintained. The crushed coal is delivered to a 24 in. conveyor and finally to the 700-ton bunker over the ovens.

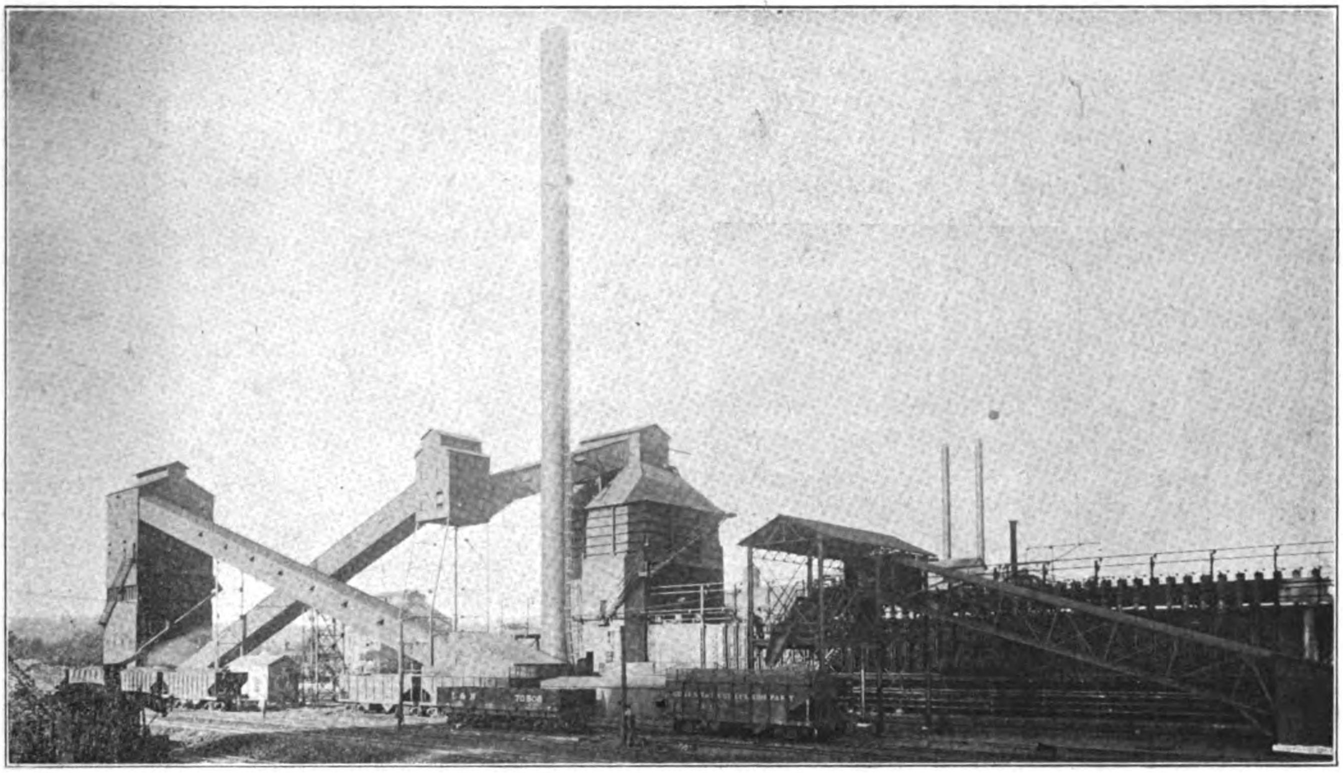

Fig. 1—View of by-product coke plant.

All coke and coal handling machinery, conveyors, etc., are of the Robins Company type.

Two Connersville positive type gas exhausters driven by Ball vertical non-condensing steam engines (one unit being in reserve) handles the gas from the ovens to the primary coolers and thence into the By-Product building where the gas is freed from the tar by P. & A. extractors and then through reheaters, thence through saturators (lead lined) for ammonium sulphate. A 5-ton Morgan electric crane handles the sulphate stock either from pit or into box cars for shipment.

The wash oil is handled by the usual circulation pumps, tanks, superheaters, etc. The continuous still consists of 16 trays, 6 ft. in diameter; total height of still being 22 ft. The wash oil coolers are of the gray or open type, there being 8 banks, 30 pipes high and 20 ft. long.

There is one crude still 10 ft. in diameter, 16 ft. long which has a working capacity of 8,000 gallons. The column consists of the usual cast iron trays and dephlegmotor.

There is one pure benzol still, 10 ft. in diameter, 16 ft. long and working capacity of 8,000 gallons.

There is an agitator of 4,500 gallons (lead lined) driven by vertical steam engine.

The usual storage tanks for finished or salable products are installed over a concrete pit. A benzol loading station with overhead tanks for various products and steam driven loading pumps take care of the loading of salable products into tank cars or drums.

The usual Koppers acid regenerating plant for regenerating the sulphuric acid used in the agitator.

Normal coking time is 17 hours, gross.

The coal used is that from the company's Virginia City mines and a representative analysis is, as follows:

Moisture	2.21
Volatile Matter	24.60
Fixed Carbon	68.53
Ash	6.32
Sulphur	1.02

The coke produced from this is very high grade, being very firm, dense and of uniform structure and the tendency to cross fracture is very small. A typical coke analysis is, as follows:

Moisture	2.47
Volatile Matter	.90
Fixed Carbon	90.02
Ash	9.31
Sulphur	.92

Shatter Test—76 per cent above 2 in.—24 in. drop.

Surplus gas from this department is passed through mains to either the open hearth furnaces or rod mill reheating furnaces where it is used to good advantage.

For steam, there are two 400-hp. Casey-Hedges water tube boilers, gas fired or coal fired.

Blast Furnace Department:

This consists of one furnace stack, height 90 ft.,

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bosh 19 ft. 6 in., hearth 14 ft. and top 13 ft. 6 in., equipped with McKee top and double skip. Bosh construction is of the water cooled type, 2 cinder notches and 12 tuyeres.

Cinder is handled from the furnace by hot pots to cinder dump and the slag is disposed of through a crushing plant for road work and railroads.

The hot metal is handled by ladles direct to the open hearth furnaces, although any surplus is put over a Heyl & Patterson single strand pig machine.

The stock house has a capacity of 10,000 tons of raw material. The coke is drawn from the stock house from bins directly over the skip and run over screens to eliminate the braize. This braize is blown into railroad cars by means of steam.

The furnace is filled by two larry cars equipped with scales.

There are four two-pass stoves 20 ft. x 90 ft. Four Southwark Vertical Blowing Engines, steam cylinders 42 in., stroke 60 in., air cylinders 84 in. x 60 in.

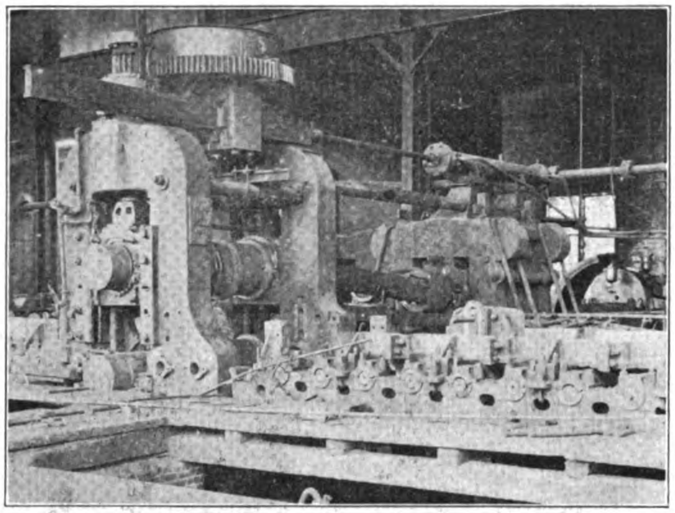

Fig. 2—View of blooming mill.

For steam there are eleven batteries of Stirling boilers, 375 hp each, gas or coal fired, equipped with automatic boiler feed together with boiler feed pumps, air compressors, etc.

There is a concrete reservoir, size 50 ft. x 246 ft. x 12 ft. equipped with three pumps, one of which is automatic. This is used as a reserve water supply for the furnace alone in case of trouble with main water supply.

Open Hearth Department.

The basic Open Hearth Department consists of six 75-ton (built for 50 tons) stationary furnaces designed and built by the Garrett-Cromwell Engineering Company, the hearths being 14 ft. x 30 ft. Each furnace is equipped with Blair water cooled ports and bulk heads, water cooled doors, door frames and roof channels.

The fuel used is producer gas from four Forter-Miller hand fired gas producers per furnace, there being 26 of these. The resulting gas averages 135 Btu per cu. ft. Two of the furnaces have Forter gas valves, the other four have valves of the mushroom type, designed and built by the company, which have given most satisfactory service. All valves are operated by hydraulic pressure.

The furnace stacks are 150 ft. high and 5 ft. inside diameter. The checker chambers are 21 ft. x 7 ft. x 16 ft. for gas and 21 ft. x 11 ft. x 16 ft. for air. No attempt is made to utilize waste heat under boilers.

Each furnace averages 15 heats per week of soft steel under .15 carbon. The charge consists of steel scrap and pig iron or hot metal in varying amounts from 30 to 70 per cent scrap according to market conditions. When using hot metal it is direct from the blast furnace for there is no mixer.

The stock loading yard has three 10-ton cranes; two Morgans and one Alliance.

In the pit are two ladle cranes, one 75-ton Morgan and one 100-ton Alliance and one 30-ton Morgan for handling slag pots. The pit equipment consists of 7 ladles of approximately 80 tons capacity and two Treadwell hot pots for slag.

Each of the two pouring platforms will accommodate 33 moulds. The size of the ingots are 18½ in. x 20½ in. and average 5,500 pounds in weight. All ingots are capped immediately after pouring.

There are two charging machines; one Wellman-Seaver-Morgan of 2½ tons capacity and one Alliance Machine Company of 3½ tons capacity. There is one 40-ton Morgan Engineering Company overhead electric crane on the floor for handling hot metal ladles (iron from blast furnace direct).

The material used for furnace bottoms is a calcined dolomite prepared at the plant, which has given excellent results. The rotary kiln in which this material is prepared is 120 ft. long and with diameter of 52 in., half of the length and 68 in. the other half. By-product gas is used as fuel. The kiln was manufactured by the Vulcan Iron Works.

The scrap used is railroad and agricultural bought in the local markets, generally in charging box size. In connection with this department there is maintained a scrap yard which prepares the scrap or rails for the furnaces.

There is a skull cracker structure for breaking pit steel and skulling the ladles approximately 60 ft. x 80 ft. In this skull cracker is one 15-ton Morgan electric overhead traveling crane equipped with E. C. & M. Company's magnet for handling drop ball, weighing 12,000 lbs. and a bucket for handling accumulated slag.

Blooming Mill Department.

The equipment consists of one 36 in. United Engineering & Foundry Company's two high mill. Rolls 36 in. in diameter; 10 ft. 8 in. long. Main spindle 9 ft.—vibration spindle 10 ft. 11 in. Pinion 36 in. x 8 ft. 9 in. staggard tooth. Operators are in pulpit in front of rolls. There are three operators and seven controllers. The screw down is hydraulically operated.

The roll table consists of a number of rolls 51½ in. x 12 in. diameter. The table is steam driven by Otis Elevator Company's double reversible engine, direct connected.

The 5 500 lb. ingot is reduced in nineteen passes to a 4 x 4 billet, 66 in., 260 pounds in weight for use in rod mill.

There are sixteen soaking pits, 6 ingot capacity, size of pits 8 ft. x 5½ ft. x 6½ ft. deep. The ingots are taken from the open hearth to stripper on mould cars pulled by dinkey engine. These cars are stripped in the blooming mill building by an electric stripper of 150 tons stripping capacity and 20 tons lifting capacity manufactured by the Alliance Machine Company. There is only one stripper used. In this same building there are two Morgan charging cranes, each 7½ tons capacity. The span for these three cranes is 62 ft. and length of runway 225 ft.

The ingots are heated with producer gas from eight Forter-Miller gas producers, which have reversing valves of the mushroom type. Producers are dry tops, 48 in. in diameter. The gases are taken off by four stacks 80 ft. high and 48 in. in diameter. No waste heat is utilized.

There is one mill table driven by a 38B, 50 hp, 220 volt D. C. Westinghouse motor controlled from rollers' pulpit by magnetic controller of E. C. & M. make. The balance of the roll tables are driven by three 25 hp 12A, 220 volt D. C. Westinghouse motors controlled from the shears. The drop table at the shears is controlled from this point and is driven by a 51D, 50 hp, 230 volt Westinghouse motor. There is one electric crane in the blooming mill building, a 30-ton Morgan, span 52 ft. and runway 260 ft. for handling rolls, etc. There is a covered crane runway 240 ft. long, 60 ft. span, on which is operated two electric overhead traveling cranes of 15 tons capacity (one Morgan and one Alliance) which are used for handling billets from this mill for sales purposes.

The mill is driven by one 48 in. x 60 in. Todd Twin reversing engine.

The shears are driven by a simple, vertical engine made by the United Engineering & Foundry Company.

While there are eight 375 hp Stirling water tube boilers, coal fired, they are not used; steam being furnished from the nearby rod mill boilers.

A typical 12-hour turn produces 600 gross tons.

Rod Mill Department.

The 4 x 4 billets from the blooming mill are conveyed by roll tables direct to the hydraulic pushers at the rod mill department. These billets are pushed into four reheating furnaces built by the Alex Laughlin Company, gravity discharge, 8 ft. 3 in. x 42 ft. long (inside dimensions). Two of these furnaces are fired by producer gas and the other two by by-product gas. The producer gas is regulated by cast steel valves and conveyed to the furnaces by underground flues. In these furnaces the billets rest on water cooled pipes. They are discharged on mill feed tables and conveyed to the continuous mill, of which there are seven stands 16 in.

The rod mill is of the Garrett type built by the Garrett-Cromwell Engineering Company. In addition to the continuous mill there are three stands 12 in. and eight stands 10 in.

The 16 in. mill is gear driven by one direct connected Allis tandem-compound 34 in. x 54 in. x 60 in. (No. 1 engine). The balance of the mill up to the finishing rolls is driven by Allis-Chalmers cross-compound, 48 in. x 84 in. x 60 in. (No. 2 engine) and the finishing rolls are driven by a Porter-Allen cross compound 28½ in. x 46 in. x 42 in. (No. 3 engine) located close to the finishing rolls. Nos. 1 and 2 engines being located in the power house on the opposite side of the mill. The shafts for the various rolls, other than the continuous mill, are rope driven.

There are seven reels, furnished by the Garrett-Cromwell Engineering Company, belt driven, controlled by friction clutch and manipulated by hydraulic power. The 260 lb. billet being rolled into No. 5 rods and coiled by these reels into a coil of approximately 25 in. inside diameter and 40 in. outside diameter. These coils drop on an apron link conveyor furnished by Garrett-Cromwell and are conveyed to rod buggies thence by tram track to the wire mill or rod yard.

Other equipment consists of one 15-ton Morgan electric overhead traveling crane close to the rod mill reheating furnaces, span 100 ft., runway 170 ft. This crane is used for picking the billets off the billet yard for the roll tables at such times as the blooming mill is not running.

Across the rod mill there is one 5-ton Morgan electric overhead traveling crane, span 91 ft., runway 336 ft., used for handling scrap from the rolls or changing rolls.

Serving this mill there are eight gas producers of the Duff type with dry tops.

The average production per turn is 300 tons.

Wire Mill Department.

The rods are delivered from the rod mill, a distance of approximately 300 ft., by buggies and tram track. Six bundles being loaded to each truck for the cleaning house. The necessary stem is inserted and rods handled by steam crane through cleaning house and onto ruster.

There are two bakers; one 10-track, brick flue, and one 7-track, steel pipe flue, of the Humphrey design. Coal fired.

The stocking from the bakers to the wire drawers is done by three Elwell-Parker tractors. These tractors also handle the weigh-up of the finished material.

Wire Department.

The Drawing Room is a steel frame, brick wall, composition roof, building (size 240 ft. x 360 ft.) containing six Humphrey wire drawing frames of 40 blocks each; four of which are driven direct by Crocker-Wheeler 230 volt D. C. motors of 300 hp each and the remaining two are driven by two 230 volt, 3 phase, induction motors, General Electric Company, of 400 hp each, with reduction gears.

Adjoining this is a fine wire drawing room (size 60 ft. x 100 ft.) containing two frames of 20 blocks each. On these blocks is produced wire from No. 15 to No. 20 gauge.

The bundles of rods weigh approximately 250 lbs. each. Chilled iron dies are used. The production of this department is approximately 30 per cent for nails and the balance sold as bright wire or is finished into other wire products.

Nail Department.

The finished wire is delivered to the Nail Department by Elwell-Parker tractors. In this department there are 153 Tiffin nail machines. These are operated from line shafts by four direct current motors. There being two rows of machines, the finished nails from both rows being delivered in the center and handled in ball bearing buggies to the rumblers. There are 12 of these of 15 keg capacity, each.

The necessary wooden kegs used in this department are furnished by a contractor who has a cooper shop inside of the plant inclosure.

From here the nails are delivered to two nail warehouses, size 60 ft. x 300 ft., each.

The size of the nail mill buildings are 60 ft. x 320 ft. and 60 ft. x 220 ft.

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Galvanizing Department.

This department takes up approximately 50 per cent of the output of the drawing department. The wire is annealed through lead pans. The equipment consists of three, 36 wire, take-up frames made by Humphrey & Sons, Joilet, Ill. These frames are of the worm drive type, gears enclosed and running in oil. This equipment is operated by three Crocker-Wheeler variable speed motors, 50 hp, speed 300 to 900 rpm. There is a speed reduction here down to block of 15 to 45 rpm. The output of this department is divided between the Barb Wire Department and Woven Wire Fence Department or sold as galvanized smooth wire. Size of building 120 ft. x 300 ft.

Field Fence Department.

The equipment in this department consists of 13 square mesh fence machines of the Denning type making practically all styles and gauges of square mesh woven wire fencing. Size of building 60 ft. x 200 ft.

Barb Wire Department.

The Barb Department consists of 70 machines, which produce various styles and patterns of barb wire fencing.

The necessary barb wire spools are sawed from lumber nailed together in this department. Size of building 60 ft. x 240 ft.

Throughout these buildings there is a complete line of wire goods manufactured including cement coated nails, blued nails, staples, bale ties, straightened and cut wire, etc.

In addition to the nail warehouses already mentioned, there is a fence warehouse, 60 ft. x 480 ft., and a warehouse for barb wire, 60 ft. x 380 ft.

All buildings are of substantial character and floored with wood blocks. There being approximately 289,200 sq. ft. of floor space in the various wire departments.

The entire roof of the wire mill is divided into alternating high and low sections, each 20 feet wide and extending across the full width of the buildings.

Power.

The power equipment consists of 8 hand fired, coal burning, 375 hp Stirling water tube boilers; 6 stoker fired, coal burning, 375 hp Stirling water tube boilers; 8 stoker fired, coal burning, 500 hp Stirling water tube boilers. The stokers are of the type "E" made by the Combustion Engineering Company. Forced draft is maintained by two simple horizontal engines (Troy Engine Company) driving two Sirocco fans (American Blower Company). These boilers furnish power for the blooming mill, rod mill and power plant.

The rod mill is driven by three steam engines, as follows (previously mentioned):

No. 1—Allis Tandem Compound 34 in. x 54 in. x 60 in.

No. 2—Allis-Chalmers Cross Compound 48 in. x 84 in. x 60 in.

No. 3—Porter-Allen Cross Compound 28½ in. x 46 in. x 42 in.

The exhaust from these three engines operate two low pressure turbo-generators made by the Westinghouse Electric & Manufacturing Company. These are 2,000 kw, 2,300 volt, 3 phase, 3,600 rpm. These generators furnish all of the necessary power for the entire plant.

However, there is as a reserve, as follows:

In No. 2 Power House.

1—1,200 kw, 250 volt D. C., 84 rpm, Crocker-Wheeler Generators driven by one Allis-Chalmers cross compound 30 in. x 60 in. x 60 in. engine.

2—250 kw, 250 volt D. C., 200 rpm, Crocker-Wheeler engine sets driven by two Buckeye cross-compound engines 14 in. x 28 in. x 21 in.

Over this equipment there is an electric overhead traveling 10-ton Morgan crane, the span of which is 69 ft. and runway 357 ft.

In No. 1 Power House.

2—450 kw, 250 volt D. C., 135 rpm, Crocker-Wheeler engine sets driven by two Buckeye cross-compound engines 21 in. x 36 in. x 30 in.

2—150 kw, 250 volt D. C., 150 rpm, Westinghouse engine sets driven by Porter-Allen simple horizontal engines.

Bar Mill Department.

Located outside of the plant inclosure and within one-half mile of the plant is a merchant bar mill which includes a 20 in. mill and a 13 in. mill.

All sizes of merchant bars from 4 in. rounds to ½ in., 6 in. flats to ¾ in. in width and 4 in. squares to 7/16 in. are made on these mills, rolled from new billets.

General.

The water supply is from Will's Creek located approximately one-half mile from the plant, an all year stream of water, which is sufficient for the plant water supply and turbine cooling water.

All switching and tracks inside of the plant inclosure are owned and maintained by the company and there are six standard switch engines and three dinkeys for the necessary switching service.

For handling the necessary raw materials to and from stock piles there are five locomotive cranes of the following make:

1—25-ton Browning.
1—20-ton Industrial.
1—10-ton Industrial.
1— 6-ton Osgood.
2—10-ton Brown Machinery Company.

READY TO CONSTRUCT TUBE WORKS AT GARY

Construction is to be started at once on the proposed plant of the National Tube Company at Gary, Ind., according to Chairman E. H. Gary of the United States Steel Corporation. The plant, which will manufacture lap and butt weld tubes, will cost $15,000,000, according to estimates, and will have an annual capacity of 350,000 tons. This will add 20 to 25 per cent to the capacity of the Steel corporation's plant tube mills.

Announcement of the corporation's intention of building the works was made originally several years ago. The plant is to be financed by the use of $5,000,000 from the corporation's cash reserve and $10,000,000 in bonds, $7,000,000 of which are a 7 per cent issue of the Indiana Steel Company and $3,000,000 a 5 per cent issue of the National Tube Company. The bonds were underwritten by J. P. Morgan & Company and already have been subscribed.

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Steel For Forge Welding

By FRANK N. SPELLER

In this paper the principal factors—method of manufacture, chemical composition, fluxing quality, susceptibility to heat and welding temperature—affecting the welding quality of steel are discussed and the average results of 80 *tests made on forge welds of hammer-welded pipe are compared with the original material. In addition it is stated that tests have demonstrated that both steel not over* 0.15 *per cent carbon and minimum tensile strength of* 47,000 *lbs. per sq. in. and that not over* 0.20 *per cent carbon and minimum tensile strength of* 52,000 *lbs. per sq. in., are satisfactory for forge welding of pipe lines, penstocks, tank-car work and similar construction. In conclusion the writer believes that the most important consideration to produce uniformly good results in the forge welding of steel, is suitable material, well-trained operators and adequate facilities for the control of operations.*

THE welding quality of steel, and the strength and reliability of such welds, depend on a number of factors, which include principally: methods of manufacture, composition, susceptibility to heat, fluxing quality, the mechanical appliances for handling and controlling the work, and the skill of the operator. There are so many factors present affecting the results that it is often difficult to determine which of these predominates in any particular case. This paper discusses particularly the characteristics of steel for forge welding, with brief reference to other factors which enter the problem.

Material and Workmanship.

Method of Manufacture. Wrought iron is most easily welded, probably on account of the presence of about one and one-half per cent of easily fusible cinder, which enables the metal to be welded at a comparatively low temperature and protects it from injurious oxidation at high temperature. For this reason wrought iron can usually be welded without much difficulty, but on account of the presence of this cinder internal defects such as laminations and blisters are more likely to occur after the metal has been brought up to the welding heat. What we term "soft welding steel" may be made by the Bessemer or open hearth process and should be made especially for this purpose, i. e., it should have, as far as possible, sufficient of the characteristics of wrought iron to readily form a "welding scale" at the lowest possible temperature. Very highly refined open hearth steels, "ingot iron" or electric steel, are, as a rule, lacking in this respect and so far have not shown as good welding quality as soft welding steel or wrought iron. Possibly these may be improved in this respect, but while these metals possess many advantages for other purposes, they do not at present appear to be well adapted for forge welding.

Composition. It is well known that comparatively small quantities of nickel, chromium and silicon interfere seriously with welding. Each of these should be under 0.05 per cent. Carbon has a lesser effect and should preferably be low, certainly under 0.30 per cent for any kind of forge welding. The higher the carbon, the lower the melting and burning point of the steel. By the burning point we mean the temperature at which the grain growth has increased to such a degree as to cause actual disintegration and intergranular oxidation of the metal. Sulphur under 0.05 per cent is not harmful and under certain conditions more may be present without injurious results. Phosphorus up to Bessemer limits is beneficial to welding.

Self-Fluxing Quality. On heating iron or steel above 1500 deg. F. an oxide scale is formed. The relation between the fusibility of the oxide scale to the temperature at which the metal "burns" is one of the most important factors determining suitability of the metal for welding. This scale consists usually of the magnetic oxide of iron (Fe_3O_4) with a certain percentage of "sonims"† from the iron (MnO, P_2O_5, SiO_2, etc.) which tend to make the scale more fusible. The method of manufacture and composition of steel have much to do with the formation of a suitable welding scale. The range of temperature between the melting point of the scale and the burning point of the metal is about 100 deg. F. in good welding steel and distinguishes this class of steel probably more than any other property. In fact, it is this self-fluxing quality which makes possible the commercial welding of iron and steel. Artificial fluxes, such as borax, may be used to lower the melting point of the scale in welding small parts of high carbon steel, but at present this is not practicable to apply satisfactorily when working on a large scale. The fusion of the scale also affords the operator a definite indication of the welding point, giving him close control over the operation.

Susceptibility of Metal to Heat. When normal wrought iron or steel is heated above the upper critical point (about 1570 deg. F. for soft steel) the grain grows at a rate depending on the temperature and time of heating. When a certain grain size is reached, a disintegration of the metal occurs with intergranular oxidation and the metal becomes "burnt." When this occurs, the metal is red-short and cold-short and useless for most purposes. The actual temperatures at which iron or steel is burned depends as much on the protective character and fusibility of the welding scale as anything else. High carbon steels are more susceptible to damage of this kind in welding than the same class of steel of lower carbon but the carbon is not the only factor, otherwise we might expect highly refined open hearth steel or "ingot iron" to weld as easily as charcoal iron.

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*For presentation at the Spring Meeting, Atlanta, Ga., May 8 to 11, 1922, of the American Society of Mechanical Engineers, 29 West Thirty-ninth Street, New York.

†Solid non-metallic impurities in steel, H. D. Hibbard, Trans. A. I. M. E., vol. xli, p. 803 (1910).

The large granular structure caused by exposure of the metal to welding temperature may be reduced to a fine structure (unless the metal has been excessively overheated) by a certain amount of mechanical forging applied while the metal is cooling or by reheating the metal to about 30 deg. F. above the upper critical point, followed by cooling in the air, which with soft steel may be comparatively rapid.

Welding Temperature. To produce intercrystalline union of two pieces of iron it is necessary that the clean surfaces be brought into close contact with a certain pressure. This is possible even at normal temperature with application of sufficient pressure in the case of soft steel, or may easily be done at a temperature slightly above the fusing point of the scale with comparatively little pressure, or at a lower temperature if the fusion point of the scale is lowered by the use of artificial fluxes, such as borax. So that the most favorable temperature for welding depends on the material and mechanical facilities. The usual temperature at which soft steel is found to weld satisfactorily ranges from 2500 to 2600 deg. F.

The skill and experience of the operator is, of course, a considerable factor in all welding. However, this is offset in forge welding to some extent by the facilities given him for controlling the heat and the work

Results of Tests.

A number of tests of forge welds (80 in all) made on two rings cut from the ends of hammer-welded pipe about ½ in. thick, compared with the original material taken from the same pipe, 90 deg. from the weld, gave results which are summarized as follows:

Material Away from Weld—Average transverse tensile test.	
Elastic limit, lb. per sq. in.	32150
Ultimate strength, lb. per sq. in.	52790
Elongation in 8 in., per cent	29.7
Reduction, per cent	58.6
Efficiency of Weld—Test pieces machined to uniform thickness.	
Average of all tests (80 tests), per cent	92.7
Average at extreme end (40 tests), per cent	90.3
Average 2 in. or more away from end (40 tests), per cent	95.0
Minimum at extreme end, per cent	69.0
Minimum 2 in. or more away from end, per cent	82.3

The above steel before welding ranged in tensile strength from about 47,000 to 62,000 lbs. per sq. in.—most of it being under 57,000 lbs. and under 0.16 per cent carbon.

Specifications.

This brings us to the question of specifications for steel best suited for forge welding. While skillful operators can undoubtedly make a good job of most steels when the carbon does not exceed that of flange quality, it seems desirable, everything considered, to limit the carbon to about 0.15 per cent for important parts where life and valuable property are at stake and a high efficiency of strength of weld is desired.

The present A.S.T.M. specification (A78-21-T) for forge-welding steel calls for steel of not over 0.18 per cent carbon having a minimum tensile strength of 50,000 lbs. per sq. in. A.S.T.M. Sub-Committee II of Committee A-1 now have under consideration substituting for this two grades of steel having the following chemical and physical properties:

	Grade A	*Grade B*
Chemical Composition		
Carbon, per cent*	not over 0.15	not over 0.20
Manganese, per cent	0.35 to 0.60	0.35 to 0.60
Phosphorus, per cent	0.04	0.04
Sulphur, per cent	0.05	0.05
Physical Tests		
Tensile strength, lb. per sq. in.	not under 47000	not under 52000
Yield point, lb. per sq. in.	not under 25000	0.5 tensile strength
Elongation in 8 in., per cent	not under 26	not under 24

*For plates over ¾ in. thick, 0.02 additional carbon is permissible.

Steel of both grades has been forge-welded and used in large quantities with an assumed weld efficiency of 90 per cent. The tests we have made indicate that this figure is warranted for pipe lines, penstocks, tank-car work and similar construction. A somewhat lower efficiency or higher factor of safety should, of course, be used for boilers and Class A unfired pressure vessels.

Boiler Code Requirements.

With respect to steel for forge welding, Part I, Section I, Par. 186 of the Boiler Code requires that:

> The ultimate strength of a joint which has been properly welded by the forging process shall be taken as 28,500 lbs. per sq. in., with steel plates having a range in tensile strength of 47,000 to 55,000 lbs. per sq. in. Autogenous welding may be used in boilers in cases where the strain is carried by other construction which conforms to the requirements of the Code and where the safety of the structure is not dependent upon the strength of the weld.

Section III, paragraph L-29 reads:

> The ultimate strength of a joint which has been properly welded by the forging process shall be taken as 28,500 lbs. per sq. in., with steel plates having a range in tensile strength of 45,000 to 55,000 lbs. per sq. in. Autogenous welding may be used in boilers in cases where the strain is carried by other construction which conforms to the requirements of the Code and where the safety of the structure is not dependent upon the strength of the weld.

The proposed section on unfired pressure vessels with reference to forge weldings, Pars. 5 and 8, reads:

> The ultimate strength of a joint which has been properly welded by the forge process shall be taken as 65 per cent of the tensile strength of the plate.

This weld efficiency seems rather low for Class A vessels and we believe that it should be still higher for Class B vessels.

In Pars. 2 and 3 of Sections I and III, firebox and flange steel are specified *for all parts* of the boiler. There seems to be a conflict in these specifications between the requirements for steel which may be forge welded, although apparently the intention is to use a steel of lower carbon for this purpose. This would seem to be in line with the best experience, but inasmuch as flange steel has apparently been successfully used for some time in forge welded boiler construction where part of the stress is carried by riveted straps, there would seem to be no reason for not continuing this practice when the weld is so reinforced.

Finishing.

After the weld is made, internal strains remain in the metal which should be released by annealing. This may be done by heating the piece uniformly to a red heat (about 1500 deg. F.) and allowing to cool in the air. Any objectionable amount of distortion which has occurred in the welding operation should be removed, preferably while the piece is at an annealing heat; otherwise it should be reformed and then annealed. Nothing has been said as to the method of welding, scarfing, preparation of the plate, or fuel to be used, as these vary considerably and good results have been obtained with widely different methods of working. Some operators prefer one form of scarfing, others none at all. Some use roller welding machines, but the majority use power hammers.* Good welding has been done with coke fire, producer gas, natural gas and water gas, the last being adapted for forge welding on a large scale.

To produce uniformly a high weld efficiency, the most important considerations are: suitable material, well trained operators, and adequate facilities for control of the work.

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*Details of mechanical appliances for hammer welding in modern American plants will be found in articles by E. F. Thum in *Chemical and Metallurgical Engineering*, September 21, 1921, October 19, 1921, and November 16, 1921.

Heat Losses From Steam Line Pipes

Losses from Bare and Covered Wrought-Iron Pipe at Temperatures Up to 800 Deg. F. Where High Temperature Superheated Steam Is Running—Investigations Made in the Mellon Institute.

By R. H. HEILMAN, Pittsburgh, Pa.

THE purpose of this paper is to report some of the data obtained recently on bare pipes operating at temperatures up to 800 deg. Fahr., and to present curves and formulas which will enable the engineer to solve readily the problems usually encountered in the calculation of heat losses from bare and covered pipes.

Bare-Pipe Heat Losses.

Manufacturers of pipe coverings often are required to guarantee that the application of a specified heat-insulating covering will effect a certain percentage saving of the heat which would be lost entirely from a bare pipe. Since the bare-pipe loss is the 100 per cent value against which the losses from the covered pipe must be compared, it is essential that the loss from the bare pipe shall be known accurately.

Many investigators have studied the heat losses from bare pipes. Perhaps the most noteworthy of these experimentalists was the French physicist Péclet. Paulding, in his book on Steam in Covered and Bare Pipes, has worked out the theory of heat losses from bare pipes in the light of the researches of Péclet. However, the findings of later investigators do not support the results given by Paulding. Owing to the fact that Péclet's experiments were conducted at very low temperatures, while subsequent investigators confined themselves mostly to one pipe size only, the Mellon Institute deemed it advisable to carry on the research to higher temperatures and to pipes of various sizes. By testing pipes of various sizes under the same condition, it was thought that more reliable data could be secured than by comparing the results of other investigators on pipes of various sizes under different conditions. Accordingly, tests were made on 1-in., 3-in., and 10-in. pipe.

The method of testing was practically the same as that described by G. D. Bagley in his paper on Conversion of Heat Losses from Pipes and Boilers, presented before the Society in 1918, except that the pipe-covering tester had been improved. A Leeds & Northrup type K potentiometer was substituted for the millivoltmeter, and a General Electric saturated-core-type voltage regulator and smaller thermocouples were added. Fig. 1 shows a view of the laboratory and the testing apparatus.

When conducting tests on bare pipes it is very desirable that the room temperature remain constant throughout the work, for the rate of heat loss is dependent upon the absolute temperature as well as upon the temperature difference. The 1-in. pipe was selected for test at the higher temperatures, as the relatively small amount of heat loss from a 1-in. pipe could not greatly affect the room temperature.

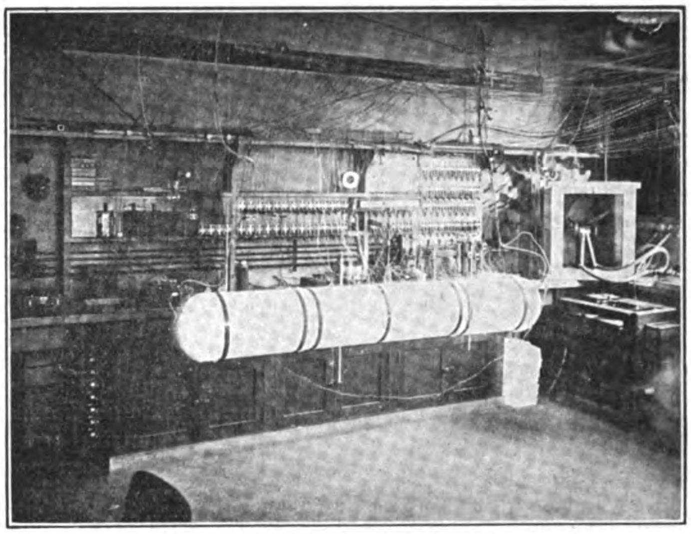

Fig. 1—Laboratory and Testing Apparatus.

This pipe was run up to a temperature of 800 deg. Fahr. The average room temperature throughout this test was 81 deg. Fahr. and the temperature did not vary more than 1.8 deg. Fahr. during its progress.

When the emissivity coefficient is plotted against the heat loss, it is found that the curve obtained is not a straight line, but falls off at the higher temperatures. This means that the heat loss from a bare pipe does

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not increase as rapidly at the higher temperatures as would be anticipated. A possible explanation for this condition is that the convection loss at the higher temperatures does not increase as rapidly as at the lower temperatures.

The first test on the 1-in. pipe was checked by a second test on another 1-in. pipe and both tests corresponded exactly at the higher temperatures.

The location of the curves for the 3-in. and the 10-in. pipes was obtained by experiment at the lower temperatures, as indicated by the solid lines in Fig. 2. The values for the higher temperatures are the result of extending the curves parallel to the curve obtained for the 1-in. pipe. This procedure was necessary because of the fact that the larger pipes could not be raised to the higher temperatures without raising considerably the temperature of the room. Tests are now in progress to ascertain the loss from vertical iron pipes, and the results will be reported later.

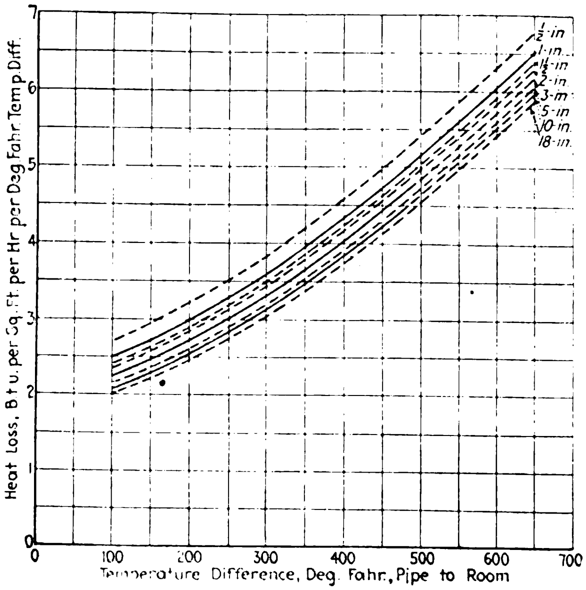

Fig. 2—Bare-Pipe Loss Curves.

In Table 1 the loss in dollars and cents and in pounds of coal per 100 lineal feet of horizontal bare iron pipe is tabulated for temperatures up to 664 deg. Fahr. The loss varies from $1.32 for 100 lineal feet of ½-in. pipe at 180 deg. Fahr. to $297.50 for 100 lineal feet of 18-in. pipe at 664 deg. Fahr.

Theory of Heat Loss From Insulated Pipes.

In order to calculate the loss of heat from an insulated pipe or boiler, it is necessary to know the total temperature drop from the pipe to the surrounding air; and to enable one to make accurate calculations it is required that the component temperature drops be known.

The total temperature drop from the steam inside a pipe to the outer air can be considered as made up of four components, as follows:

(a) Drop from steam to the outer surface of the pipe.
(d) Drop from outside surface of the pipe to inside surface of the insulation.
(c) Drop from the inside surface of the insulation to the outside surface of the insulation.
(d) Drop from outside surface of the insulation to the surrounding air.

The temperature drop from the steam to the outer surface of the pipe depends upon the resistance to heat flow offered by the film at the inner surface and the resistance offered by the iron wall of the pipe.

This combined resistance is very low, owing to the high conductivity of the iron and the relatively high conductivity of the water film. Consequently the temperature drop is very low. No attempt has been made to measure the above temperature drop in this investigation, as it was considered to be so small as to be negligible. This drop has been measured for saturated steam by L. B. McMillan[*] and found to be a fraction of a degree. However, a test conducted by Eberle[†] for superheated steam shows a drop as high as 10 deg. Fahr. This drop should be taken account of when making calculations for superheated steam.

The temperature drop from the outside surface of pipe to the inner surface of the insulation depends upon the resistance to heat flow offered by the air space between the surface of the pipe and the inner surface of the insulation. The heat flow which takes place in this case is due to radiation, conduction, and convection. Since the radiation increases as the fourth power of the absolute temperature difference, it is to be expected that the temperature drop would tend to decrease at the higher temperatures.

The temperature drop from the outer surface of the pipe to the inner surface of the covering for 1-in., 3-in., and 10-in. pipe is shown in Fig. 3. These curves show that the temperature drop increases as the pipe diameter decreases. A test was also made on a 3-in. pipe with an air space of 1.2-in. between the surface of the pipe and the insulation. By comparing this curve with the curve for an air space of 0.1 in., it is observed that the temperature drop for a 1.2-in. air space is only a few degrees more than for an air space of 0.1 in. This is probably due to the fact that for air spaces much greater than 0.2 in. convection currents are increased, thus causing an increase in heat loss.

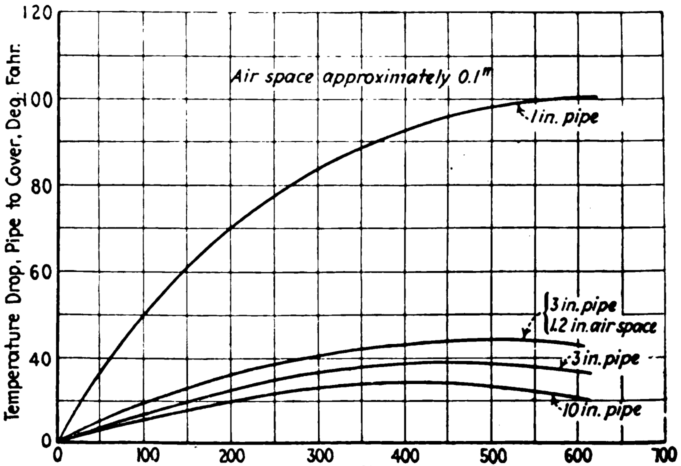

Fig. 3—Temperature Drop from Outer Surface of Pipe to Inner Surface of Covering.

Since the flow of the heat is directly proportional to the cross-sectional area, and inversely proportional to the length of the path, it is obvious that the presence of a 1.2-in. air space between the surface of the 3-in. pipe and the inner surface of the insulation will cause an increase in the total amount of heat lost from the surface of the pipe, provided, of course, the air space is not as good an insulator as the covering itself. In this case the insulating value of commercial coverings is many times greater than the insulating value of the air space.

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[*] Trans. Am. Soc. M. E., vol. 37, p. 928.

[†] Mitt. uber Forschungs-Arbeiten auf dem Geb. des Ing., helf 78.

The results of this test show that an air space of over 0.25 in. is of little use as an insulator on flat surfaces at high temperatures, and that this air space is of little value as a protection to the covering from the effects of the high temperatures. This test also demonstrates that coverings should be kept as close as possible to cylindrical surfaces, because the insertion of an air space of approximately 0.1 in. between the pipe and insulation actually increases the overall loss. An examination of Fig. 3 shows that the temperature drop for a 0.1-in. air space is approximately equal to that for 0.1 in. of commercial insulations, so that this temperature drop can be neglected in calculations and the pipe covering considered as fitting close to the pipe with the pipe temperature and the temperature at the outer surface of the covering as the temperatures bounding the covering.

The temperature drop from the inside surface of the insulation to the outside surface of the insulation depends upon the resistance to heat flow offered by the insulation itself. Heat is transmitted through the insulation by means of radiation, conduction and convection. The relative amount of each of these three factors depends entirely upon the construction of the insulating material.

The amount of heat transmitted through the insulation and the temperature drop from the inner to the outer surfaces determine what is generally called the absolute conductivity of the insulation. However, this does not give the true absolute conductivity of the insulation, but gives what may be called the mean absolute conductivity. The true absolute conductivity for an insulating material, say, 1 in. in thickness can be represented by a curve. The absolute conductivity for a given material increases as the temperature increases, and therefore the absolute-conductivity curve depends upon the thickness of the covering and also upon the curvature of the covering.

The drop in temperature, or the temperature-gradient curve through the insulation, then depends upon the thickness of the covering and the curvature. In a cylindrical covering the resistance to heat flow diminishes as the outer surface is approached, the temperature drop becomes less, and the gradient curve is bowed downward if the curvature alone is taken into consideration. However, the absolute conductivity decreases as the outer surface is neared, with a consequent bowing up of the gradient curve, and the two tend to counteract each other, so that the temperature-gradient curve may be bowed either up or down or be a straight line, depending upon the curvature of the cylinder. The temperature-gradient curve for a flat surface should bow up.

It is highly desirable that tests should be conducted on commercial steam-pipe coverings of different thicknesses and at different temperatures, in order to obtain mean absolute-conductivity curves for the different thickness.

The temperature drop from the outer surface of the insulation to the surrounding air depends upon the **amount of heat emitted by radiation and air contact.**

TABLE 1—LOSSES FROM HORIZONTAL BARE-IRON STEAM PIPES[1]

From 100 Lineal Feet of Pipe per Month of 30 Days with Steam in Pipes 24 Hr. per Day. Coal at $4.00 per Ton of 2,000 Lb.

Gage Press.	Hot Water			10 Lbs.			80 Lbs.			120 Lbs.			160 Lbs.			200 Lbs.			200 Lbs. and 100° F. Superheat.			275 Lbs. and 250° F. Superheat.		
Temp.	180° F			239.4° F.			324.0° F.			350.0° F.			370.7° F.			387.9° F.			487.9° F			664.3° F		
Pipe Size	Dollars Loss	Pounds Coal	B.T.U. per Lineal Ft. per °F. Diff. per Hr.	Dollars Loss	Pounds Coal	B.T.U. per Lineal Ft. per °F. Diff. per Hr.	Dollars Loss	Pounds Coal	B.T.U. per Lineal Ft. per °F. Diff. per Hr.	Dollars Loss	Pounds Coal	B.T.U. per Lineal Ft. per °F. Diff. per Hr.	Dollars Loss	Pounds Coal	B.T.U. per Lineal Ft. per °F. Diff. per Hr.	Dollars Loss	Pounds Coal	B.T.U. per Lineal Ft. per °F. Diff. per Hr.	Dollars Loss	Pounds Coal	B.T.U. per Lineal Ft. per °F. Diff. per Hr.	Dollars Loss	Pounds Coal	B.T.U. per Lineal Ft. per °F. Diff. per Hr.
½"	1.32	526	.605	2.24	897	.670	3.92	1566	.779	4.51	1805	.815	5.25	2010	.846	5.53	2210	.875	8.60	3440	1.040	16.15	6460	1.375
1"	1.91	763	.878	3.26	1305	.973	5.72	2290	1.138	6.25	2601	1.178	7.27	2910	1.242	8.07	3230	1.280	12.56	5026	1.520	30.55	12220	2.600
1½"	2.65	1060	1.220	4.54	1818	1.357	7.98	3190	1.586	9.28	3710	1.676	10.42	4165	1.751	11.36	4550	1.804	17.94	7175	2.170	34.30	13720	2.920
2"	3.24	1297	1.491	5.36	2142	1.600	9.78	3910	1.943	11.37	4549	2.052	12.75	5100	2.145	14.00	5600	2.220	22.10	8825	2.670	42.20	16890	3.590
2½"	3.86	1545	1.778	6.65	2660	1.984	11.66	4660	2.320	13.66	5460	2.464	15.25	6100	2.564	16.70	6690	2.650	26.64	10650	3.220	50.50	20200	4.300
3"	4.56	1824	2.100	8.24	3292	2.460	13.88	5550	2.760	16.14	6450	2.910	18.04	7210	3.030	19.84	7945	3.150	31.60	12640	3.820	58.25	24300	5.170
3½"	5.18	2070	2.380	8.89	3554	2.655	15.82	6325	3.145	18.31	7322	3.305	20.50	8200	3.450	22.60	9040	3.580	35.90	14360	4.345	69.00	27600	5.860
4"	5.78	2305	2.650	9.87	3950	2.950	17.70	7075	3.520	25.50	8200	3.700	22.85	9145	3.842	25.15	10060	3.981	40.10	16040	4.850	72.40	30920	6.580
4½"	6.35	2540	2.920	10.94	4370	3.260	19.48	7790	3.878	22.60	9025	4.075	25.30	10120	4.250	27.75	11100	4.400	44.05	17620	5.326	85.60	34240	7.286
5"	6.95	2780	3.200	11.97	4790	3.575	21.25	8500	4.232	24.62	9850	4.450	27.60	11050	4.650	30.40	12140	4.805	49.35	19740	5.960	94.50	37800	8.050
6"	8.20	3280	3.775	14.21	5680	4.240	25.30	10110	5.024	29.30	11720	5.295	32.80	13120	5.522	36.00	14420	5.715	57.50	23000	6.955	112.50	45000	9.580
7"	9.40	3760	4.325	16.18	6470	4.826	29.10	11640	5.782	33.70	13480	6.090	37.60	15040	6.324	41.60	16650	6.560	66.25	26500	8.010	129.00	51550	10.97
8"	11.00	4398	5.050	18.25	7300	5.450	32.60	13030	6.455	37.65	15050	6.840	42.40	16940	7.125	46.05	18420	7.300	74.75	29900	9.050	146.20	58500	12.44
9"	11.62	4650	5.350	20.35	8130	6.070	36.25	14500	7.210	42.10	16840	7.600	47.22	18900	7.950	51.98	20790	8.230	83.50	33400	10.10	162.60	65050	13.84
10"	12.68	5065	5.925	22.05	8820	6.584	40.20	16100	8.010	46.70	18690	8.440	52.30	20910	8.805	57.75	23100	9.150	97.50	39000	11.18	180.00	72000	15.30
12"	15.00	6000	6.995	26.44	10580	7.890	47.40	18950	9.425	55.40	22120	10.00	61.76	24700	10.40	70.00	28010	11.14	109.30	43700	13.22	213.50	85500	18.18
14"	16.60	6635	7.625	28.90	11560	8.620	52.00	20800	10.34	60.50	24200	10.92	67.50	27000	11.36	74.10	29650	11.76	119.40	47740	14.43	233.00	93300	19.85
16"	18.82	7525	8.650	32.80	13120	9.790	58.76	23500	11.70	68.40	27320	12.34	76.10	30410	12.80	84.25	33700	13.35	135.00	54000	16.34	265.00	106000	22.55
18"	21.00	8400	9.650	36.10	14460	10.80	65.40	26150	13.00	76.50	30570	13.80	85.50	34200	14.38	93.75	37500	14.87	151.20	60500	18.30	297.50	119000	25.30

[1] In this table coal has been figured at $4.00 per ton of 2,000 lb., 13,000 Btu per lb. of coal; labor, boiler-room expense, etc., taken at $1.00 per ton, making total value of coal fired at $5.00 per ton. Boiler efficiency taken at 70 per cent; air temp. 70 deg. Fahr. Experimental data obtained at the Mellon Institute.

This in turn is dependent upon the nature of the surface of the body, the shape of the body, the excess of its temperature over that of objects to which radiation takes place, and the absolute value of the temperature of these bodies. Commercial steam-pipe coverings are invariably covered with a canvas jacket. From the above-mentioned facts it is obvious that the loss from a canvas surface at a given temperature is independent of what is under the canvas, so that, if the canvas-loss law can be ascertained, this law may be applied to the loss from steam-pipe coverings and thus the temperature of the outer surface of the insulation can be determined. In making calculations of heat loss through an insulation, it is absolutely necessary to know the temperatures at the inner and outer surfaces.

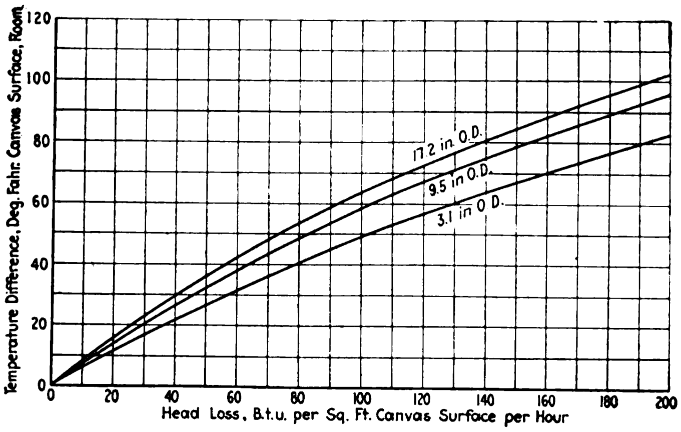

Fig. 4—Canvas-Surface Loss-Curves.

Péclet made a careful study of the heat emissivity from various surfaces, canvas surfaces included. As mentioned, however, his experiments were conducted at relatively low temperatures. McMillan made a study of the heat emissivity from a canvas surface in his study of commercial steam-pipe coverings, but he confined his experiments to one pipe size only. Nevertheless, McMillan's results in the form of a curve present a readier means of calculating the losses from steam-pipe coverings than do Péclet's, whose observations, while taking all the variables into consideration, are in too complicated a form to provide a ready means of calculation.

Since McMillan's canvas-surface-loss curve was obtained from experiments on one pipe size only, this curve can be used in making calculations on coverings of a diameter approximately the diameter of the coverings tested. In order to be able to calculate the loss of heat from pipe coverings of any diameter, it has been necessary to obtain the canvas-surface-loss curves for various diameters. Accordingly, coverings were tested on the 1-in., 3-in., and 10-in. pipes used in determining the bare-pipe losses. The average outer diameters of the coverings used were 3.1 in., 9.5 in. and 17.2 in. The results of these tests are shown in Fig. 4.

In order to simplify the calculations necessary to determine the loss of heat through coverings of various diameters, the equations of the three curves shown in Fig. 4 have been derived. In these equations—

T_d = temperature difference between canvas surface and room, deg. Fahr.

h = total Btu loss per hour per square foot of canvas surface.

D = outer surface diameter, inches.

$$\text{3.1 in. diameter: } T_d = \frac{272.5\,h}{h + 456.5} \quad \ldots\ldots [1]$$

$$\text{9.5 in. diameter: } T_d = \frac{272.5\,h}{h + 368} \quad \ldots\ldots [2]$$

$$\text{17.2 in. diameter: } T_d = \frac{272.5\,h}{h + 328.4} \quad \ldots\ldots [3]$$

These equations can be combined to give the general equation:

$$T_d = \frac{272.5\,h}{h + \frac{564}{D^{0.19}}} \quad \ldots\ldots\ldots\ldots [4]$$

which is approximately accurate for diameters up to 2 ft.

It is believed that these curves are fairly accurate, inasmuch as they were obtained from the results of numerous tests on different materials.

Thermocouples were used in determining the canvas temperatures. During this investigation, it was found that the couple, when just inserted under the canvas, would invariably read low. This difficulty was overcome by inserting it under the canvas for a distance of several inches, this distance depending upon the size of the couple and the temperature of the covering. From a theoretical consideration of the question, it can be shown that the minimum distance to which the thermocouple can be placed under the canvas is reached when the temperature of the thermocouple wires, a short distance from the junction, is the same as the temperature at the junction. When this condition is reached, there is no flow of heat from the junction to the wires and consequently no lowering of the junction temperature.

Sample Calculations.

A covering 2 in. thick, having a mean absolute-conductivity coefficient of 0.56, is placed on a 4½-in. outside-diameter pipe maintained at a temperature of 400 deg. Fahr. The temperature of the surrounding air is 70 deg. Fahr. Determine the heat flow in Btu per hour per sq. ft. of pipe surface.

The heat flow through a cylinder is given by the equation:

$$H = \frac{K\,(T_1 - T_2)}{r_1 \log_e \frac{r_2}{r_1}} \quad \ldots\ldots\ldots\ldots\ldots [5]$$

where T_2 is the temperature at the outer surface of the covering. To obtain T_2, knowing only T_1, the pipe temperature and T_3, the room temperature, it is necessary to change the form of the equation so as to include T_d. The equation for T_d, as developed from experimental results, is

$$T_d = \frac{272.5\,h}{h + \frac{564}{D^{0.19}}} \quad \ldots\ldots\ldots\ldots [4]$$

whence

$$h = \frac{K\,(T_1 - T_3 - T_d)}{r_2 \log_e \frac{}{r_1}} \quad \ldots\ldots [6]$$

in which

h = Btu loss per hour per sq. ft. of canvas surface.
K = mean absolute conductivity of insulation.
r_1 = radius of inner surface of insulation, inches.
r_2 = radius of outer surface of insulation, in inches.
T_d = temperature difference between outer surface of insulation and room, deg. Fahr.

Substituting in [6], there results

$$h = 0.56 \left[\frac{400 - 70 - \dfrac{272.5\,h}{h + \dfrac{564}{8.5^{0.19}}}}{4.25 \log_e \dfrac{4.25}{2.25}} \right]$$

$$= 0.207 \left(330 - \frac{272.5\,h}{h + 375}\right)$$

$$= \frac{-363.1 \mp \sqrt{363.1^2 + 4 \times 25{,}600}}{2} = 60.4$$

$$H = 60.4 \times \frac{4.25}{2.25} = 114 \text{ Btu loss per hr. per sq. ft.}$$

of pipe surface.

The temperature at the outer surface of the covering can be obtained by substituting the value of **h** in the equation $T_d = \dfrac{272.5\,h}{h + 375}$, reducing to $T_d = 37.6$. Therefore the temperature of the outer surface of the covering is

$$37.6 + 70 = 107.6 \text{ deg. Fahr.}$$

Material-Handling Equipment as Used in the Iron and Steel Industry

A Description of the Handling Machinery Used in the Manufacture of Steel from the Time the Ore Leaves the Mines Until the Steel Goes Through the Last Process at the Mill.

By F. L. LEACH, New York, N. Y.

THE iron and steel industry probably requires a greater diversity of material-handling equipment than any other type of manufacturing, because of the enormous bulk and weight to be handled. From the time the material leaves the mines until it is turned out of the mills as finished product it is constantly being moved by heavy conveying machinery of all descriptions. It is the intention of the author to describe this equipment with the idea of bringing out weak points in present day practice, and possibly open the way to strengthen the weakest links in conveying methods used.

2. As the principal object of this paper is to describe the machinery used about the industrial plant, just a brief description will be given of the handling methods before the material reaches the plant.

3. The ore is mined and conveyed to convenient lake ports by means of special gondola cars. The latest type of these cars is designed to carry 120,000 lbs. The total weight of car is 33,500 lbs., therefore the ratio of revenue load to total weight is 78.1 per cent. A good example of a modern port is the Duluth, Missabe & Northern Railway docks at Duluth, Minn., the No. 5 dock of which has the greatest storage capacity of any on the Great Lakes. It is 2,304 ft. long, has 384 pockets, and a storage capacity of 134,400 tons.

4. At the present time ore handling on the Great Lakes is carried on by a fleet of vessels unequalled anywhere in the world. Some of these vessels are capable of handling a cargo of 15,000 tons, and are over 600 ft. long. During the year 1916, 66,658,466 tons of ore were carried by the vessels from the upper Great Lakes to southeastern ports. The steamer *Homer D. Williams* carried 462,490 tons during the season of 1920.

5. Vessels equipped for self-unloading have been developed for handling stone and ore. The hold in such cases is divided into bins, which deliver the material by gravity to a belt coneyor running lengthwise of the vessel; this conveyor delivers the material to an elevator which hoists it to another belt conveyor suspended in a horizontal position from the masts of the vessel and capable of being moved radially and vertically like the boom of a derrick. This belt conveyor delivers to the storage pile on the dock, and it is possible to distribute the material onto the dock at any point or height desired within the scope of the boom conveyor.

6. Ore-unloading equipment has probably been developed to the highest point of efficiency at the ports on the Great Lakes. An example of this is Ashtabula Harbor on Lake Erie, where there are eight Hulett ore unloaders having a capacity of 15 tons each. They have a record of unloading seven boats of a total capacity of 77,000 tons in 22 hours actual time. Four 17-ton capacity machines of this type have unloaded a cargo of 13,000 tons in 3 hours and 25 minutes.

7. These unloading machines remove the ore from the boat and dump it directly into railroad cars for shipment to inland plants, or they place it in a bin located at the rear of the machine where it may be picked up by a traveling ore bridge and placed in storage piles.

.8 Railroad cars have been developed for handling ore up to 120 tons capacity. Ore shipped to inland plants in bottom-dumping cars may be unloaded directly into

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*For presentation at the Spring Meeting, Atlanta, Ga., May 8 to 11, 1922, of the American Society of Mechanical Engineers, 29 West Thirty-ninth Street, New York.

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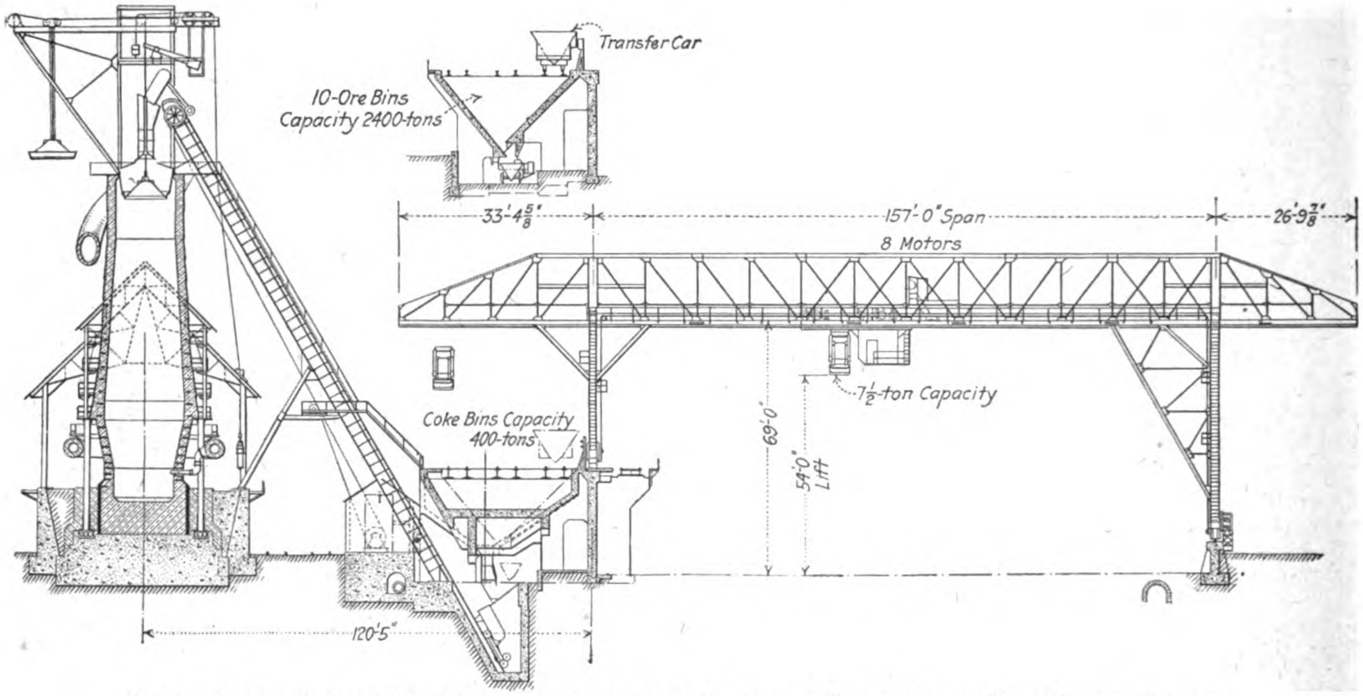

Fig. 1—Section through blast furnace and ore yard showing relations of ore bridge, bins and furnace.

bins by gravity. However, the modern method is to use a traveling rotary car dumper, which can be spotted at any point in the length of the ore yard. The cars of ore are placed one at a time on the dumper, turned upside down and the ore dumped into a concrete pocket that extends the full length of the ore yard. An ore bridge, similar to the one shown in Fig. 1, distributes the ore to the storage pile in the yard. Rotary car dumpers have been developed so that three men can unload about 20 cars per hour.

9. Cars of 240,000 lb. capacity have been designed with a total dead weight of 78,800 lbs., giving a ratio of revenue load to total weight of 75.4 per cent.

10. The traveling ore bridge is another valuable link in material-handling equipment and is used in many different ways in handling the ore at unloading docks. Some machines are designed for the purpose of removing the ore directly from the boats, in which case it may be placed in its proper location in the ore yard without rehandling. But in the case mentioned above, the bridge is used for distributing ore in the yard after the unloaders have removed it from the boat. This is the most economical method where large quantities are to be handled.

11. One of the largest bridges of this type ever built is 612 ft. long overall, and is used at the Western Pennsylvania Dock Company at Cleveland, Ohio. This bridge handles a 15-ton bucket and covers an ore storage of over a million tons.

12. Fig. 1 shows how these bridges may also be used to place the ore and limestone in bins, preparatory to sending them to the blast furnace. Several different types of bins are used, although the principle is the same in each. The ore is placed in the bin either by the ore bridge, or by gondola-type hopper cars and it passes down through the bin by gravity as required, through a shut-off gate into a lorry car. The types of bins ordinarily used are the overhead design shown in Fig. 1 and the tunnel type in which the lorry car goes through a tunnel beneath the bridge.

13. The choice of these two types is decided by the topography of the land on which a plant is built and by climatic conditions. From the bins an electrically driven weighing lorry car is used to convey ore, limestone and coke to the blast furnace skip hoist.

14. Fig. 1 shows how material is conveyed from the stock yard and bins to the top of the blast furnace, dumped into the bell hopper by the skip car, and finally deposited inside by the well known double bell system. Two of the products of the blast furnace are pig iron and slag, which are drawn off at the base in a molten state. Both iron and slag were formerly allowed to run from the furnace into sand molds and handled after cooling. Most plants today, however, run the molten iron and slag directly into ladles supported on special cars. In this way the iron is transported either to a pig-casting machine where it is cast into pigs, or to a mixer at the open hearth plant, where it is kept in the molten state, or further refined before it is placed in the Bessemer converter, for the duplex process. The molten pig iron may also be conveyed direct to the open hearth furnace for the straight open hearth process.

15. The slag is disposed of in various ways, since it has become of considerable commercial value in the last few years. After having been allowed to cool it is crushed to various sizes, and then used in the place of crushed stone.

16. The Croxton method is one way of handling slag. By this method it is dumped into concrete pits across the bottom of which heavy chains have been laid at intervals of about five feet. When the pit has been filled with slag to a depth of about 18 in. to 24 in. the chains are pulled up through the slag by an overhead crane. This breaks up the slag so that it may be conveyed by means of the crane and grab bucket to a crusher at the end of the slag pit.

17. Another method is to dump the molten slag into a pit partly filled with water, thereby granulating it so that it may be removed by the crane and a grab bucket. This granulated slag makes a very good railroad ballast.

(To be continued)

Eastern Company Rebuilds Blast Furnace

The Thomas Iron Company at Hokendauqua, Pa., Have Completed the Reconstruction of Their No. 3 Blast Furnace. Additional Power Facilities and a Pig Casting Machine Also Installed.

By RICHARD PETERS, JR.
Manager of Sales, Pulaski Iron Company

THERE hangs on the walls of the office of The Thomas Iron Company in Easton, Pa., a frame enclosing a document which is unique in the annals of the iron trade, in that it records the inception of the only American company which has continued to manufacture pig iron exclusively for nearly 70 years without reorganization or without having a change in its corporate name. This interesting relic is the original autographical list of the 26 subscribers to the stock of the company, showing the names, addresses and amounts taken by each, and attests to the incorporation of The Thomas Iron Company on April 4, 1854.

The project was started, however, nearly two months earlier than this date, as the result of a meeting of prominent men of the Lehigh Valley, interested in the development of the anthracite iron industry, just then getting under headway. A resolution adopted at the original meeting named the company in honor of David Thomas, who conceived the new undertaking and who had been the pioneer in the successful manufacture of anthracite iron on a commercial scale. The original capitalization of $200,000 represented a considerable outlay for those days, as it took courage to invest largely in a venture so new as that of smelting iron with a fuel of which many iron masters were skeptical.

Even before the state had granted the charter of incorporation, a site for the erection of works had been purchased, on the west bank of the Lehigh river, a short distance north of the Lehigh Crane Company's plant at Catasauqua. The farm land acquired on which to build the furnaces and town site was named "Hokendauqua," the derivation being from the language of the Delaware Indians and meaning "Land Seeking." Arrangements were made to promptly start the erection of two blast furnaces, to be known as numbers one and two, and contracts were placed for the necessary engines, boilers and other iron work. The stacks were built of masonry, following the practice of those days, and they had extensions to the tunnel heads like Turkish minarets. When the plant was completed and put in blast in 1855, it was the subject of much favorable comment, so much so that Percy in his 'Metallurgy," published in London in 1864, states that the Thomas works "stand pre-eminent" as illustrative of American manufacture by reason of its "beauty, size and convenience of build, and for its historic interest." Detailed drawings and descriptions as well as records of the furnaces are incorporated in the work of Percy. Prior to this, in 1859, Prof. Lesley, the Secretary of the American Iron Association, described the Thomas furnaces in the following language: "Built together and alike, 18 feet across the bosh and 60 feet high, and blown by two blast cylinders in common, at the extraordinary pressure of 8½ pounds to the square inch, these twin stacks have steadily kept in advance of all the other furnaces of the United States. In 1856 they made 17,446 tons together. In a word here stands the demonstration that a large and well built crucible, properly stocked with good ores and properly blown with power to spare, must be a great and continual success."

The supplies of raw materials were conveniently located at Hokendauqua, especially the brown hematite ores, which abounded in the neighboring counties. Access to these ores, however, was by teaming only, at a considerable expense, so that two years later we find the Thomas Company joining the Crane works in building a railroad to the ore district. The road was named the "Catasauqua & Fogelville," and while now controlled by the Reading System, yet The Thomas Iron Company still retains its original interest in the company. In 1882, the Ironton Railroad was purchased so that control could be had of the ore and limestone reached by its line, but at the present time this road is more important as a cement carrier, due to the developments of this industry in the region.

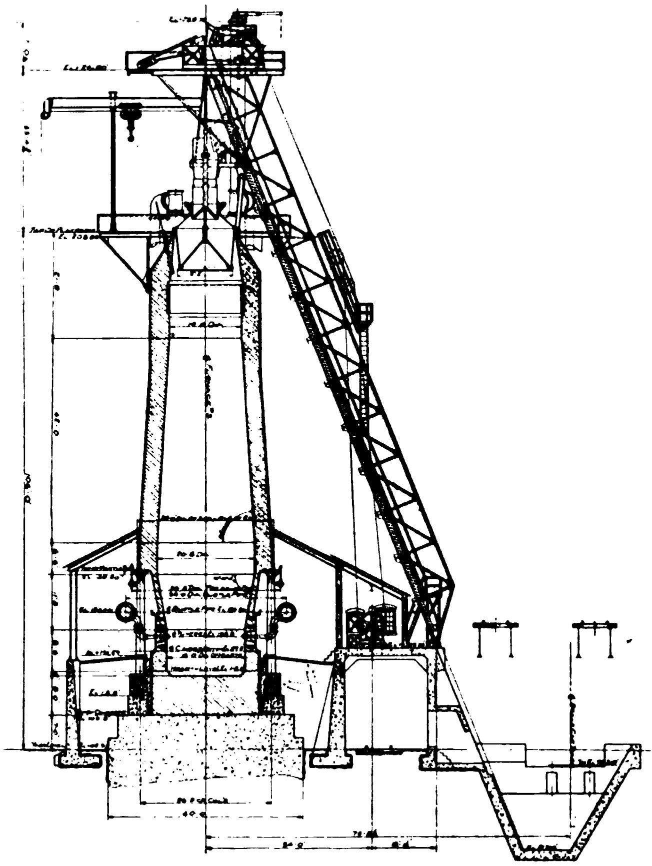

Fig. 1—Cross section of furnace.

The needs of the country for pig iron during the Civil War prompted the erection in 1862 and 1863 of two additional stacks of the same general construction as the original ones. In 1868 the plant of the Lock Ridge Iron Company at Alburtis was acquired, and an additional furnace was erected at that place the following year. With its increased production, the Thomas company had already taken a foremost place among American iron makers by the latter end of the sixties; nevertheless in 1873 and 1874 two more units were built at Hokendauqua. These were also of stone construction, but just why the management did not follow the advanced engineering of the times by using the iron shell on columns is an open question, unless there was some idea of retaining the symmetry of the original works.

In this connection, it is of interest to note that by the purchase, in the latter part of 1884, of the furnaces of the Saucon Iron Company at Hellertown, the Thomas company obtained possession of two of the earliest stacks to be built in this country of iron shells. Prior to the addition of the Saucon plant, the Keystone furnace at Island Park, near Easton, was acquired and it can well be imagined that by this time the Thomas company was an important factor in pig iron production. It is true that in the early eighties it led the United States in merchant iron output, and was outranked in Pennsylvania only by the famous Edgar Thomson plant, and that of the Cambria Iron Works. Additional production was accomplished through the lease of the Lucy furnace at Glendon about 1887, but as the unit was a small one it was not long retained by the Thomas interests. By reason of the commanding position of the company, its monthly quotations letters were for many years the means of establishing the eastern iron market.

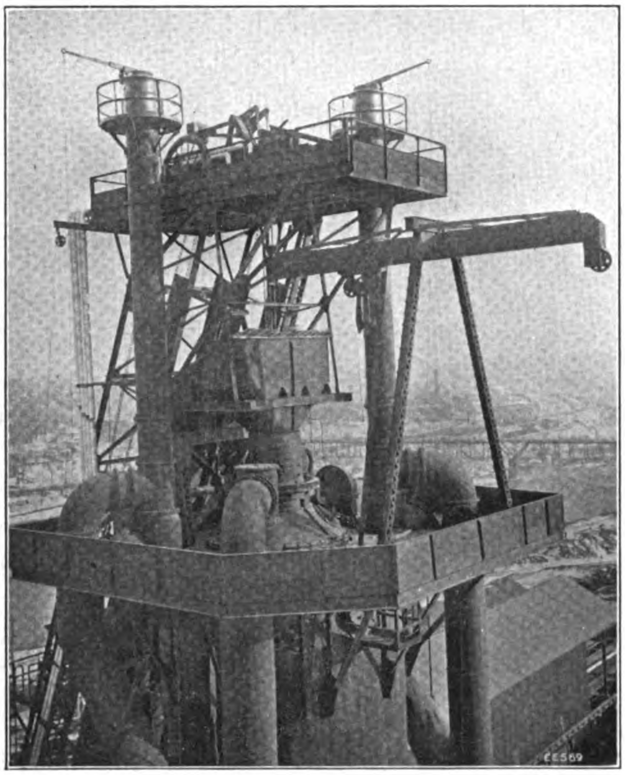

Fig. 2—View of furnace top, showing McKee Revolving Distributor, downcomers, etc.

At the close of the first half century of the career of the company, the number of operating furnaces had contracted to nine, with an annual output, however, of nearly 100,000 tons greater than in 1884. This fact was the result of the rebuilding of numbers one and three furnaces at Hokendauqua, so that this plant alone was able to produce more iron at this time than was made at all the works at the zenith of the career of the company, measured by the number of its furnaces. The first stack to be reconstructed was number one, which was accomplished by the tearing out of its twin unit, thereby making room for a modern steel shell of the day, with fire brick stoves added in 1897. Five years later the number three furnace was rebuilt in a similar manner, while the fourth old stone stack was abandoned. Fire brick stoves were used to replace the original iron type at number six stack, and after many years of good work there, they were removed to Alburtis to augment the equipment of that plant.

With the coming of the period of replacement of a number of small units by larger furnaces with increased outputs, the Thomas company followed the order of the day by concentrating their improvements at Hokendauqua. The remaining stacks of the stone stack era were abandoned and partially dismantled, and skip hoists replaced the hand-filling arrangements of numbers one and three furnaces. This improvement necessitated a rearrangement of the stocking system so long in vogue. The original layout of the entire plant consisted in having the stock houses and casting sheds parallel to each other, and at right angles to both the Lehigh Valley Railroad and river. This arrangement was satisfactory in the old days of light, close coupled equipment, but with the advent of modern ore and coke cars, the short curves gave considerable trouble. Each stock house was served by a bridge, carrying the tracks over those of the Lehigh Valley road, which was obviously an inadequate arrangement, with the further disadvantage of stock delivery on dead-end trestles.

The policy of the management of The Thomas Iron Company is to centralize their operating activities at the main plant at Hokendauqua, utilizing the outlying smaller units for special iron or for caring for abnormal demands of the market. One of the Saucon stacks has recently been torn down, and the Keystone furnace was sold during the war period to the Northern Ore Company, and the remaining units at Hellertown and Alburtis have been put in good operating condition.

Reconstruction of the Hokendauqua plant has made good headway by the recent completion of the rebuilding of the number three furnace, while plans have been made for eventually enlarging the number one stack, thereby centering the work done around the enlarged two furnace plant. Number three furnace as rebuilt is about 300 feet north of the remains of the old stone stacks, and about 150 feet south of the number one. The blowing engine house, boiler plant, and pig casting machine are along the Lehigh Valley tracks north of the furnace sites and the stoves, dustcatchers and gas washers are west of the furnaces, immediately adjacent to the railroad. The stock bins are east of the furnaces, and are reached by an elevated track crossing the Lehigh Valley tracks above grade at the north end of the plant.

The designing and rebuilding program was handled under a general contract by Arthur G. McKee & Company of Cleveland, Ohio, and was under the direct supervision of Mr. W. A. Barrows, Jr., President, and Mr. C. E. Hulick, Superintendent of The Thomas Iron Company.

The No. 3 stack was completely rebuilt from the foundation up. The foundation is concrete, octagonal in

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plan, with foundation bands of reinforcing rods, and measures 40 feet short diameter at the base. Eight feet of fire brick bottom blocks bring the hearth level 16 ft. above the general yard level.

The new lines of the furnace give a hearth diameter of 16 ft., a bosh angle of 79 deg. 55 min. and a height of 90 ft. from hearth level to top platform. The volume of the furnace is 17,745 cu. ft., and the total brick count in the lining 358,400 9-in. equivalents. The general arrangement of the furnace lines, top and skip bridge are illustrated in Fig. 1.

The hearth jacket is of 1⅛-in. plate, 9 ft. high, and the tuyere jacket of 1-in. plate 7 ft. 5 in. high. A steel plate bosh jacket was used, cooled by water sprays, eliminating most of the bosh cooling blocks customarily used, the former type of construction being considered preferable by The Thomas Iron Company. A new bustle pipe 4 ft. 2 in. in diameter was installed. The new furnace shell is of ¾-in. plate throughout, supported on a mantel ring of 1-in. plate, reinforced with heavy angles.

The furnace top is equipped with a McKee Revolving Stock Distributor with 5 ft. 6 in. small bell, and 11 ft. 3 in. cast steel large bell. The platform is roughly square in plan. Four downcomers of the McKee baffled type were supplied, with two bleeders and explosion valves. The top platform, distributor and downcomers are well illustrated in Fig. 2.

The upper platform for the bell operating rigs is supported on the upper end of the skip bridge. The bell cylinders are of the horizontal type, enclosed in structural frames. A 20-ton trolley was installed for handling the furnace distributor and bells. The increased height of the furnace together with the fixed location of the stock bins necessitated a very steep skip bridge. It is of the through truss type with ¼-in. deck plates and 60-lb. A. S. C. E. rails. Skip ropes are led through the bridge to the hoist engine directly below. Skip cars are of 100 cu. ft. capacity. The new hoist engine house is of brick on a concrete foundation spanning the hot metal running track. The new hoist engine has 12x14 in. cylinders with a 60-in. drum and was built by the Otis Elevator Company.

The Pugh type 75-ton hot metal ladle cars were provided. The new pig casting machine was designed and installed in a structure suitable for housing a second machine when found necessary. This machine, which is of the Uehling type, was manufactured by the Pittsburgh Coal Washer Company, and installed by the McKee Company.

Additional power requirements were met by the erection of five 514-hp. Connelly boilers. These boilers were designed for 160 lbs. working pressure and were erected in batteries of two, provision being made for the addition of three more boilers in the future. Boilers are equipped with Kling-Weidlein aspirating burners for blast furnace gas. Steam piping was installed by the shown in Fig. ... Steam piping was installed by the Pittsburgh Piping & Equipment Company as subcontractors under the McKee Company.

Three reciprocating boiler feed pumps were installed and a feed water heating of 6,000 hp. The pumping requirements of the water purification plant were met by the installation of two centrifugal motor driven pumps, each with a capacity of 1,000 gallons per minute. A water purification plant of sufficient capacity for the furnace plant was installed by the Wm. B. Scaife & Sons Company in buildings erected by the McKee Company.

Other additions and changes consisted of new buildings for pumps, new cast house, alterations to trestles, skip pit and bins, changes in gas mains, water and steam piping and other minor items necessary to make the plant modern and complete in every respect.

CONFERENCE ON NON-FERROUS ALLOYS

A conference of the Advisory Committee on Non-Ferrous Alloys of the Institute of Metals Division of the American Mining and Metallurgical Engineers with representatives of the United States Bureau of Mines was held at the Bureau of Mines, Washington, D. C., April 25. This was the second meeting held for the purpose of developing a program of co-operation between the non-ferrous metal industries, as represented by the Institute of Metals Advisory Committee, and the Bureau of Mines, with especial reference to the non-ferrous work of the latter organization.

The conference discussed the question of the functions and possibility of development of the proposed Alloys Research Association, now known as the Alloys Research Information Service. As originally proposed, it was the idea to receive contributions of $250 each from firms in the non-ferrous metal industry for promoting a central information service. A fund of $40,000 was required for this work, which would begin as an information and abstracting service and later develop into a central research laboratory. The feeling was that, owing to the depressed industrial situation, it would not be a propitious time to push the matter. Members representing industrial concerns stated that their companies would be willing to enter such an association when conditions are better.

The work of the Ithaca, N. Y., station of the Bureau of Mines on the effect of inclusions on the endurance of alloy steels was outlined by Dr. H. W. Gillett, who mentioned the rise of temperature test as a method for facilitating fatigue tests and showed the importance of the problem in both ferrous and non-ferrous metals.

The question of refractories for the Ajax-Wyatt furnace was brought up by William B. Price of the Scovill Manufacturing Company. It was stated that a number of companies were working on the problem, and it was suggested that their interests and information be pooled. The facilities of the ceramic section of the Bureau of Mines were offered as a clearing house for information in regard to refractories for the furnace.

Dr. R. B. Moore, chief chemist of the Bureau of Mines, outlined a proposed plan of investigation by the steel industry, the Bureau of Mines and the Bureau of Standards in regard to the effect of inclusions on the fatigue resistance of steels.

The desirability of investigating copper-lead alloys was discussed.

R. J. Anderson, metallurgist of the Bureau of Mines, outlined the results of recent work at the Pittsburgh experiment station in regard to (1) the contraction of aluminum alloys, (2) removal of stress in brass tubing, and (3) heat treatment of cast non-ferrous alloys.

Clyde E. Williams, superintendent of the Northwest experiment station of the Bureau of Mines, Seattle, Wash., gave an account of experiments made on preparing cast iron from sponge iron and steel scrap in the electric furnace, particularly as to the effect of various factors on the rate of carbon absorption.

W. M. Corse of the Monel Metal Products Corporation brought up the question of centrifugal casting and suggested that the investigation of the process might properly fall within the scope of the Bureau of Mines.

The Hot Rolling of Gears

Recent Development and Perfection of a Process Whereby the Successful Production of Gears by Rolling Blanks Heated to a Forging Temperature Is Made Possible.

By REGINALD TRAUTSCHOLD, M.E.
Consulting Engineer*

ALTHOUGH the reduction of gears has in the past been primarily in the province of the machinist, the recent development and perfection of a process based on a well known principle has brought it within that of the forger—through the successful production of gears by rolling blanks heated to a forging temperature. This accomplishment has long been recognized as theoretically possible and was attempted as early as 1872 by John Comley, who endeavored, but unsuccessfully, to mold gear teeth on a heated blank by a knurling process. Several more recent attempts to produce gears by the same or a similar process were equally unproductive of results, the failure in each case being due to the fact that the inevitable slippage which occurred was overlooked and no attempt was made to counteract it. In all these early experiments only one of the functioning shafts of the rolling apparatus was positively driven. As the rotation of the die roll was thus entirely dependent on that of the blank or vice versa, the resulting slip between the two caused serious distortion of the teeth on the molded gear and destroyed accuracy in tooth spacing.

The one additional factor necessary to the successful development and perfection of a gear rolling process was neglected until some 10 years ago when H. N. Anderson conceived the idea of positively actuating both of the functioning shafts and accurately synchronizing their rotation by means of suitable timing gears. Experiments with this improved apparatus conclusively demonstrated that it eliminated entirely the slippage between the die roll and the blank, and the resulting distortion which had caused the failure of previous attempts to roll gears. Mr. Anderson's idea in developing his process and constructing his first machine was merely to replace the preliminary gashing operation of the prevalent method of gear cutting and then to finish the gears by the usual grinding processes. However, the first machine, completed in 1911, not only proved successful in molding accurately spaced teeth, but also teeth so perfectly that any further finishing of the teeth was unnecessary. This initial achievement won for him the award of the John Scott Legacy Medal by the Franklin Institute in 1915.

The Die Roll Problem.

The problem of ultimate perfection of the process thus became primarily one of developing a system of die rolls which would form perfect and efficient gears with a high degree of accuracy at low cost and which could be redressed when necessary without affecting the precision of form of the molded teeth. The perfection of such a system of dies and their adaptation to use on a practical and efficient machine operating on the principle evolved have now made feasible the commercial production of gears by a true molding process.

The solution of the problem of dies offered little difficulty, as the plane sided tooth of the standard involute rack and the characteristic tooth of the standard crown gear, for rolling spur and bevel type gears respectively, met all requirements of economy and precision in production of the dies and of ease and economy in refinishing. These two forms proved readily adaptable for the production of all types of gearing in commercial use, and of several other types, such as the bevel herringbone, which is not possible of production by any cutting process.

The Rolling Process.

In the actual process of rolling gears, the blank, heated to a temperature of from 2000 to 2100 deg. F., is mounted on the work arbor of the rolling machine and securely clamped in place by means of a powerful automanipulation. The arbors carrying the die roll and the heated blank are actuated by suitable, heavy timing gears and the die and blank are rolled together in synchronized contact under a rolling pressure of from 10 to 20 tons. At the start of the rolling, the die is clear of the blank, but advances gradually until the teeth of the die have penetrated the blank to their full depth. This advancement is accomplished by means of smooth positive cam action which produces a regular constant progression of the die until very near the point of full penetration, and then a somewhat slower progression until the die and molded gear are fully engaged. The action of this cam mechanism is so timed as to effect full penetration of the die roll teeth just before the blank has cooled to its critical temperature and then to permit continued rolling with no die advancement until the blank has cooled somewhat below this temperature, the final stage of the process serving to planish and polish the teeth formed.

As the rolling is done, as a rule, at speeds varying from 400 to 700 revolutions per minute, it is obvious that the advance of the die roll per revolution is very slight. This fact assures a very thorough kneading and working down of the metal of the blank and permits the easy and free flow of the metal as it is displaced and built up by the die. The fact that both the die roll and the blank are positively driven and accurately synchronized assures the die teeth penetrating the blank radially at exactly the same point on each revolution, effectively guarding against any tooth distortion in the finished product.

Cooling the Dies.

During the rolling operation the die drill is cooled by a stream of water directed against its face at a point opposite to that of contact with the blank. This cooling, in view of the fact that the entire rolling consumes less than 15 seconds, prevents the temperature of the die rising above that easily bearable to the hand. The chilling effect of the comparatively cold, wet die roll on the hot blank causes a rapid contraction of the heated blank and consequent loosening of the forging scale as it is formed. The loosened scale is then thrown free by the centrifugal force due to the high speed of rotation of the blank. Since the rolling is continued until after the blank has cooled below the critical temperature, or in other words, until after the formation of forging scale has ceased, the finished gears are entirely free from scale and the formed teeth are not only perfectly shaped and unmarred by scale blemishes, but are highly polished on all contact surfaces.

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*The Anderson Rolled Gear Company.

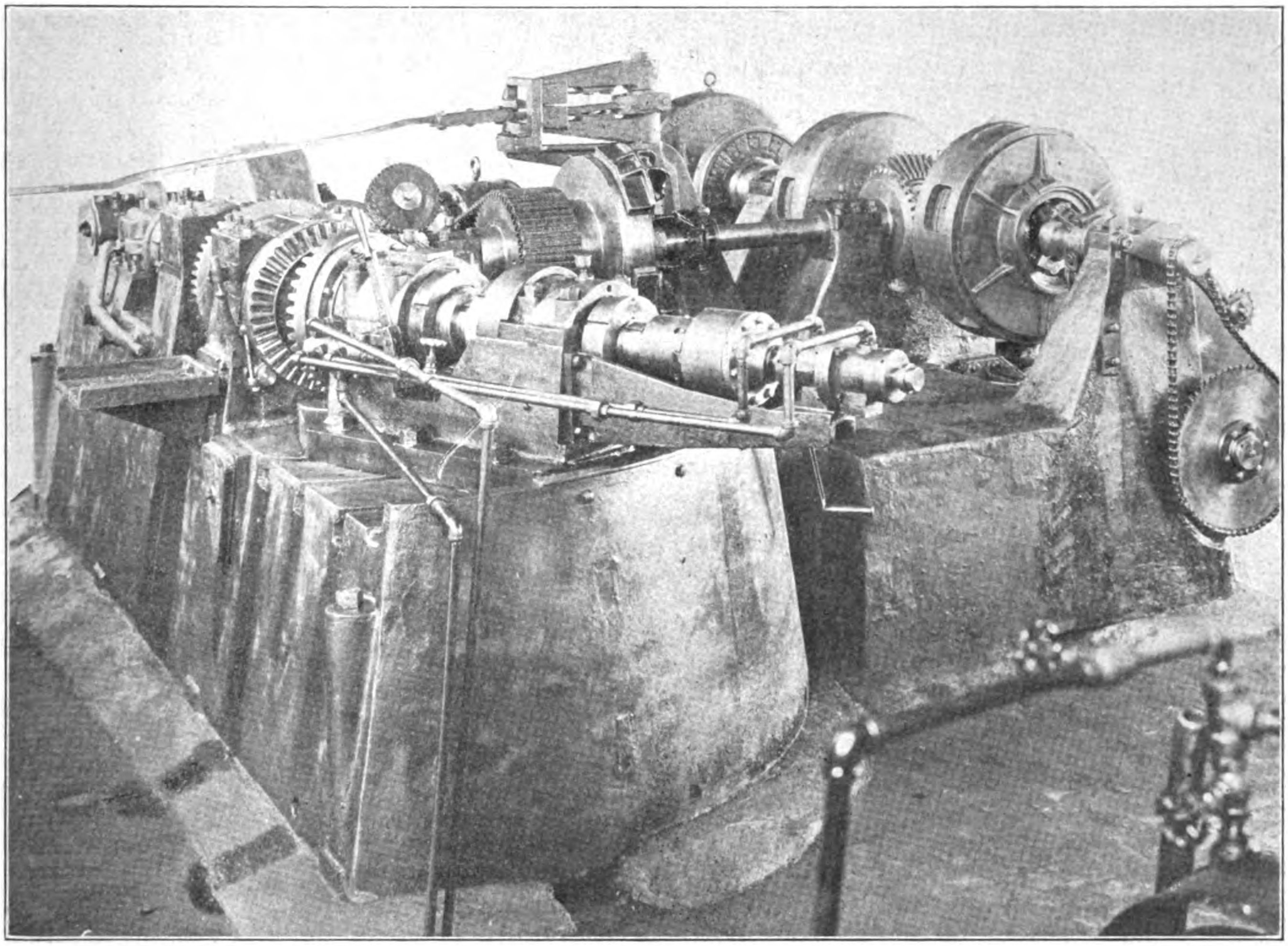

Fig. 1—Front and side view of bevel ring gear (K) machine.

No further finishing operations are required except on the bore and faces of the hubs and on the ends of the teeth. For these operations, which may be easily and semi-automatically performed on standard machines, the gears are chucked on the accurately rolled teeth, thus assuring perfect centering.

Oscillating Attachment.

In order to attain the highest degree of precision in the form of the teeth molded, machines designed for the production of the most accurate gears are equipped with additional mechanism for frequently and automatically reversing the rotation of the die and blank. This frequent reversing or oscillation, at somewhat reduced speeds, varying from 80 to 200 revolutions per minute, is maintained during the forming of the molded teeth and until the die is within 0.01 inch of full penetration. The action then automatically reverts to high speed direct rolling for the planishing effect. The oscillating methods tend to effect displacement and building up to a somewhat more equal and constant degree on both sides of the teeth than if rolling in one direction is maintained, thereby producing a more perfectly symmetrical tooth form.

Forms of Die Rolls.

But two forms of die rolls are necessary for rolling all types of gears in general commercial use. For all spur gears the adopted master form tooth is that of the standard involute rack, simply wrapped around the pitch circumference of the die roll, irrespective of the diameter or number of teeth. The high degree of precision attainable in the formation of these dies—they are the form most easily and accurately reproduced by mechanical means—assures a corresponding perfection in the teeth formed on the molded gears. The profile curvatures of teeth so molded obviously differ slightly from those of the standard involute system, thus sacrificing that theoretical advantage attributed to involute gears, of a slight axial adjustment without impeding the functioning of the combination. The loss of this advantage is, however, of small consequence as it is of little or no value in actual practice. In the first place, gears in actual use are almost invariably mounted on shafts in fixed positions; secondly, the inherent inaccuracies of cut involute gears are undoubtedly sufficient to destroy any practical advantage of possible adjustment. In any event this characteristic is of negligible importance compared to the economic advantages of the simple die roll tooth design.

The master form of die tooth is applicable to the formation of helical or spiral spur gears by making the tooth spaces of the die in the form of oblique straight cuts across its face, although the resulting tooth spaces are somewhat deeper at the center than at the ends. On gears molded from these dies the teeth are, of course, somewhat shorter and heavier at the ends than at the center, but gears so formed are actually stronger than gears of the same pitch with teeth of uniform dimensions, as the great central tooth depth tends to increase the arc of contact at the center of the face.

Herringbone gears may be as accurately and cheaply produced as the other types by the simple expedient of a compound die roll, made up, to enable easy redressing, of two helical die rolls of opposite spiral angle, keyed and securely bound together when functioning, and readily taken apart for separate refinishing of the two halves. Accurate alignment of the two parts of these dies produces the monolithic teeth essential to maximum strength. Not only can perfect herringbone spur gears be formed by this method, but application of compound die rolls to bevel gear rolling produces as readily and as cheaply a bevel herringbone gear, which can be made by no other method, and may conceivably prove of even greater value in machine construction than the herringbone gear of the spur type.

For the production of all types of bevel gearing the crown gear form of tooth is used and in many cases a crown gear type of die roll. If, however, the gear to be rolled is to be of a given number of teeth of a certain pitch, such as the standard pitches now in general use, its diameter is also definitely fixed. As the diameter of a crown type die roll is established by the length of the conical element of the gear to be rolled, it is apparent that the circumference of the crown gear die roll may not be commensurably proportional to that of the blank. The crown gear die roll would not, therefore, accommodate a full number of teeth of the given pitch, but this may be overcome by the use of a flat bevel die roll, shortening the diameter of the die until it is commensurably proportional to that of the gear blank.

Die Roll Proportions.

As the actual operation of molding the plastic gear blank ceases when the blank has cooled to just below its critical temperature and before there is any appreciable increase in the temperature of the die roll, it is, of course, necessary to design and proportion the dies for molding gears at that critical temperature. Consequently, the dies must all be somewhat oversize as compared with the finished gears at normal temperatures. In designing the dies this allowance for shrinkage can be determined only empirically, but the laws governing the action of metals under variations of temperature and the coefficients of expansion have been so accurately established that a high degree of precision in proportioning the dies is possible, the gears produced being more accurate in spite of this shrinkage allowance than those produced by any of the cutting methods. Die rolls properly made and proportioned as above should produce at least 500 accurately rolled gears before any wear is apparent.

Dressing Die Rolls.

All types and sizes of die rolls having the master form of tooth can be very easily redressed whenever it is made necessary by wear. It might, however, seem that this redressing in the case of dies of the spur type would introduce inaccuracies in the product due to the inevitable slight reduction in the diameter of the die. This would undoubtedly be true if the speed of functioning shaft rotation were not controlled by the heavy timing gears, that is if the blank were not driven in synchronized contact with the die roll. As it is, the angular distance the teeth molded on the blank remains constant, regardless of any slight reduction of the diameter of the die or the thickness of the die teeth. The only effect of this modification, if appreciable at all, is to produce a slight creep between the die roll and the blank, which does not appreciably affect the profile curvature or the thickness of the molded teeth. Even a quite considerable amount of creep may be successfully absorbed by a reduction in the thickness of the die roll teeth sufficient to maintain a constant width of die roll tooth spaces.

This modification of die roll proportions in redressing is entirely unnecessary in the case of the crown or flat bevel type of die as the grinding does not affect the diameter of these types.

Shrouded Gears.

All die roll faces are somewhat narrower than those of the gear blanks, thus producing gears partially or wholly shrouded. Consequently, if it is desired to strengthen the weaker member of a pair of gears, the shroud may be left on, either entirely or partially, or the shrouds on the two gears may be so proportioned as to equalize the strength of the two and greatly increase that of the combination. The increase in strength cannot well be definitely established, but considering also the greater inherent strength of rolled teeth, it is probably a conservative assumption that shrouded gears can be proportioned and rolled which possess double the strength of ordinary cut gears of the same pitch.

Greater Inherent Strength.

The greater inherent strength of rolled gears is due to the effect on the structure of the metal of rolling at high temperature and under high pressure. This pressure and the thorough kneading action of the die teeth while the metal is in a plastic state, in addition to building up and compressing the metal into the formed teeth, gradually breaks up the normal coarser crystalline structure and produces a dense, thoroughly worked metal of almost fibrous characteristics. The minute crystals are rearranged in a truss formation following the periphery of the finished gear, thus tying the teeth to the body of the gear and equalizing the structural strains. In fact, the reduction of internal structural strains is so marked that no distortion whatever occurs in subsequent heat treament of the gears and it has even been found unnecessary to use any clamps to hold the gear true when quenching.

The modified metal structure also materially increases the hardness and wearing qualities of the gear teeth and assures a more uniform result from case hardening or other heat treatment. Exacting laboratory tests, confirmed by service tests under the most severe operating

	Machine Cut Gears	Hot Rolled Gears
Normal Condition		
Yield point	6470 lbs.	7918 lbs.
Ultimate strength	12250 lbs.	13645 lbs.
Hardness	22	26
Case Hardened		
Yield point	13529 lbs.	14750 lbs.
Ultimate strength	17250 lbs.	19130 lbs.
Hardness	87	85
Depth of case	0.027 in.	0.035 in.

conditions, have shown an average superiority for rolled gears of 25 per cent in strength and 20 per cent in hardness, as shown in the tables.

Economy of Gear Rolling.

In addition to the decided superiority in strength and hardness in the gear teeth produced, the process itself effects a very considerable saving in the cost of quantity production of gears, as compared with that of the approved cutting methods under even the most favorable of conditions. This saving applies in varying degrees to the cost of material, labor, overhead, and equipment investment.

As the rolling process is essentially one of displacement and building up, rather than of cutting away, of the metal, the blanks may be so proportioned as to require the removal of a minimum weight of metal in finishing the hubs of the gears and the ends of the teeth. The saving in actual weight of metal in the rough gear blanks thus effected ranges from 20 to 40 per cent of that scrapped from blanks for the same sizes of cut gears.

The largest machine so far developed can be easily handled by two men, an operator and a helper, the actual operation of the machine being entrusted to the operator, leaving the helper to tend the heating furnace, heat the gear blanks and feed them to the machine. Intelligent laborers under the direction of a capable foreman can readily be trained to the efficient performance of either function. When it is realized that the actual time of rolling the largest gears is less than 15 seconds, the saving in labor costs by the rolling process may be appreciated. It is only limited by the degree of dexterity attained by the crew and a production rate of 80 or 90 finished gears per hour can be readily attained and maintained. The time saving in the actual tooth forming operation alone, over the fastest method of accurate gear cutting, is from 90 to 95 per cent or even higher, while the saving in the production of completed gears ranges from 20 to as high as 80 per cent.

This advantage in rate of production effects, as well, a very substantial saving in initial equipment investment—the average being 50 per cent or more for all equipment necessary to finish the gears completely and about 75 per cent for the equipment needed in simply finishing the gear teeth. For a daily production, such as might be needed by a large manufacturer of automobiles, of 700 bevel ring gears, 700 bevel pinions, 700 miter bevel gears and 1400 spur gears, for example, the following figures showing the actual cost of the equipment necessary, demonstrate the magnitude of the saving effected by the rolling process.

TOTAL EQUIPMENT COST

Cutting Process	Hot Rolling Process	Saving
$508,500.00	$234,050.00	53.97%

TOOTH FORMING EQUIPMENT ONLY

Generating and Gashing Machines	Furnaces and Rolling Machines	Saving
$362,500.00	$91,500.00	74.76%

This saving is obviously due, for the greater part, to the smaller number of machines required to maintain any given rate of production by the rolling process and is reflected to a proportional degree in the saving in the floor space or the investment in buildings required. This is in itself no inconsiderable factor, particularly where existing plant facilities are inadequate.

To sum up the economies accomplished by the Anderson process of gear rolling—the saving of about 50 per cent in equipment investment, the 25 to 80 per cent reduction in labor costs and the 20 to 40 per cent reduction in waste material, combine to produce a saving in the total cost of production of completed gears amounting, at a conservative estimate, to from 20 to 40 per cent.

As the rolling process is essentially a true molding and a true development process, while the most accurate and efficient cutting method, the generating process, consists of two entirely unrelated movements, rotation of the blank and intermittent transverse cutting action, which can not be absolutely co-ordinated, it is obvious that rolled gears must inevitably possess a greater degree of accuracy and symmetry of tooth form and smoothness of finish. These factors directly affect the wearing qualities and efficiency in power transmission attainable in gear trains, which, considered in conjunction with the very material decrease in the cost of production and the gain in structural strength of from 25 per cent to as high as 100 per cent, in the case of shrouded gears, would seem to justify the assumption that the Anderson process promises to attain universal adoption wherever economy in quantity production of accurate gears is desired, and eventually to improve greatly the finish, wearing qualities and efficiency of gears in general commercial use. In fact, Mr. Anderson's invention of a practical gear rolling machine and the development of it, as now attained, undoubtedly represent one of the most revolutionary developments in the mechanic arts in recent years.

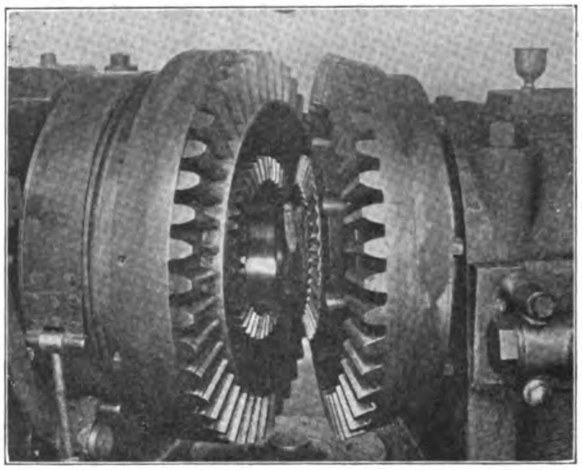

Fig. 2—Die, blank and timing gears, bevel ring gear (K) machine.

INFORMATION REGARDING TECHNICAL SOCIETIES.

The frequency of requests for information concerning scientific and technical societies has emphasized the need for a source from which this information may be quickly obtained.

The Technology Department of the Carnegie Library of Pittsburgh is meeting this need through maintenance of a card file of national societies of this type. The cards, in so far as the information is available, contain the official name of the society, the names and addresses of president and secretary, date of annual meeting, and the official "organ," or publication. A supplementary file lists those serials which regularly publish advance notices of national, state and local meetings.

It is desired to make this file complete for all scientific and technical societies in Pennsylvania and to include all sections of national and state societies having headquarters in Pittsburgh. To this end, the co-operation of local secretaries is urged. Please send information to E. H. McClelland, Technology Librarian, Carnegie Library of Pittsburgh.

Control of Silicon in the Blast Furnace

Discussion Showing How the Composition of the Iron Is Regulated by Varying the Composition in General of the Charge and by Controlling the Temperature of the Hearth.

By S. L. GOODALE
Professor of Metallurgy, School of Mines, University of Pittsburgh

EVERY modern blast furnace is operated to produce some definite kind of iron at any particular time. In order to maintain the furnace product within the narrow range of composition required for each particular use it is necessary to maintain the operation of the furnace uniform within very narrow limits.

The controlling factors in regard to kind of iron to be made are the temperature of the operation—and this refers mainly to the temperature of the hearth where the finishing reactions occur—the composition of the raw materials used, and the proportioning of the various ingredients of the charge. And when all of these factors are right to produce the desired iron it is furthermore very necessary that they should be kept right so that the furnace shall continue to operate uniformly and not be subject to changes of conditions. The commercial requirement of low cost must always be strictly observed. We will discuss certain of these controlling factors, first taking up a number of mechanical phases that contribute to the uniformity of operation, and then taking up the chemistry of the process and discussing how the composition of the iron is regulated by varying the composition in general of the charge, and by controlling the temperature of the hearth, and explain some matters concerning temperature control. By the term hearth is here meant all and only that part of the lower inside volume of the furnace where the coke is being actively burned by the blast and the iron and slag are melting. The lowest portion inside where iron and slag collect may be distinguished by the term crucible.

The basic principle of the blast furnace may be said to consist in the subjection of the iron ore to the action of certain reagents at temperatures gradually increasing up to that of the hearth. The chief reagents employed are the carbon monoxide formed by combustion of the carbon of the coke with the oxygen of the blast, the carbon of the coke acting directly, and the slag forming portions of the charge. Two main objects are sought, first, to produce pig iron of the composition desired, and at the lowest unit cost possible, and, second, to eliminate the gangue, or surplus material which occurs naturally with the ore, limestone and coke, as cheaply as may be. This latter requirement necessitates the fusion of all this material into a slag as the only practicable way of handling it.

The mechanical control of the process referred to is directed to securing the thorough interaction of the stream of gases rising in the furnace with the slow stream of solid and liquid materials descending through the same space. Channeling must be avoided. The charging of the furnace must follow a regular routine which will secure such a distribution of the various sized particles of the charge over the top of the charge column as to start the material down through the furnace with practically the same open area for the gases to pass through in any one part as in any other. This distribution must be correct in two ways, first, radially, and, second, circumferentially. Good distribution is not always easy to secure, although much effort has been expended on this matter and the apparatus in use has been developed through years of experimenting and study.

It is also advisable to have the materials of the charge in such a state of physical division that they will work their way fairly regularly down through the furnace, this meaning that the pieces charged should be neither too large nor too small, but of about a similar size throughout. It is bad, and may be disastrous, for certain parts of the charge to be so fine as either to be blown out of the top of the stack by the blast of gases, the gases having a very high carrying power for dust at that point because of their high velocity, or to run ahead of the other parts of the same charge because of being so fine as to slip down through between the larger pieces of stock. Some materials tend strongly to run ahead, in fact, certain fine dry powdered material will flow almost like water, especially when hot.

It is as necessary to distribute the blast over the full area of the hearth as it is to distribute the solid charges over the full area of the throat of the furnace. A good distribution of the blast is much more nearly obtained by the original design of the furnace being fitted to its expected operating conditions than is a good charge distribution. The blast must penetrate to the center of the furnace at or nearly at the tuyere level, and this is a distance of 10 feet in some large modern furnaces. This space, moreover, is occupied with a mass of solid coke.

We will assume that these mechanical features have been so controlled that all parts of the charge reach the various levels of the furnace on their way from the top to the hearth together as charged, except that, whereas the charge was introduced in layers of, say, coke first, then stone and then ore, when the charge has gotten a few feet down into the furnace these layers will have mixed more or less. We will further assume that the stock is everywhere distributed so as to be uniformly acted on by the gas over the whole of the area of each level, and that the blast and gases are also uniformly distributed in a similar way to act on the charge.

Then the purpose of this paper is to set forth briefly some of the fundamental chemistry of the process, and how this may be utilized to control the operation to secure a desired result, and particularly with regard to silicon. In a later paper it is intended to set forth something of the effect of silicon in the iron itself, and of the reasons for the importance of this element.

The fundamental chemistry of the operation can be stated roughly in a broad, over-all sort of way in a series of fairly definite typical reactions which consider only the raw materials and the finished products, or the products at some fairly definite stage of the operation. For the present purposes we may deal with certain parts of the chemistry in about this way. In the upper part of the shaft of the furnace most of the reduction of the iron oxides of the ores to iron is accomplished, and this is mostly done by the carbon monoxide taking up this oxygen from the oxides of iron and becoming carbon dioxide with a considerable evolution of heat. In some cases of easily reducible ores the reduction of the iron oxides to iron is practically complete within the upper levels—perhaps the upper fourth—of the shaft; in other cases a notable part of these reductions is left to be completed at the higher temperature and in the purer carbon monoxide of the hearth. Still other furnaces will run with intermediate conditions in this respect.

These typical reactions may be formulated about as follows, but it should be remembered that the reactions as stated are only types, and are not to be thought of as giving in any complete way an idea of what goes on.

1. 250°C. $Fe_2O_3 + 3CO \longrightarrow 3CO_2 + 2Fe$
2. 250°C. $2CO \longrightarrow CO_2 + C$
3. 250°C. $Fe_2O_3 + CO \longrightarrow 2FeO + CO_2$
4. 400°C. $Fe_2O_3 + 3C \longrightarrow 2Fe + 3CO$
5. 550°C. $C + CO_2 \longrightarrow 2CO$ (rapid)
6. 600°C. Deposition of carbon ceases.
7. 700°C. $FeO + C \longrightarrow Fe + CO$ (begins)
7. 800°C. $FeO + C \longrightarrow Fe + CO$ (complete)
8. 800°C. $CaCO_3 \longrightarrow CaO + CO_2$
5. 1000°C. $C + CO_2 \longrightarrow 2CO$ (prevails)
CO_2 cannot exist below the level of this temperature.
Smelting 9 $SiO_2 + 2C \longrightarrow Si + 2CO$
Zone 10 $FeS + CaO + C \longrightarrow CaS + Fe + CO$
11 $MnO_2 + 2C \longrightarrow Mn + 2CO$
12 $P_2O_5 + 5C \longrightarrow 2P + 5CO$

Table adapted from Stoughton's "The Metallurgy of Iron and Steel."

This deoxidaton of the ore oxides takes place in accordance with the chemical law of mass action, etc., and to an extent which depends on the time during which the reagents act. When we have at a high temperature a mixture of iron ore, carbon and air or the products of combustion of carbon with a limited amount of air this law of chemistry teaches that the materials will tend to react with each other until there is a certain ratio between the amounts of carbon monoxide and carbon dioxide present, which will be unchanged so long as the temperature and pressure are maintained, and unless or until any of the reacting substances is used up.

In general, those reactions will take place between the elements of any reacting group which will result in the production of the greatest amount of heat whenever heat can escape from the place where the reaction occurs or be absorbed in some way. But when heat is supplied in sufficiently large amounts from some outside source or from another more powerful reaction the reaction can be forced to proceed in the opposite direction, i. e., so as to absorb heat. In this case that reaction, of several that are possible between the reagents present, will occur first which shows the least absorption of heat; and then as the temperature increases or the supply of heat becomes greater the more difficult endothermic reactions will start, i. e., those absorbing more heat.

Figures are tabulated below to show the relative amounts of heat given off when various elements unite with a unit weight of oxygen. These figures are given as a part of the basis for the discussion of the reduction of silicon from the silica in the charge; and are put on the basis of the same weight of oxygen in all to show the relative affinity of the various elements for oxygen, the affinity being proportional, other things being equal, to these quantities of heat.

Element	Weight	Oxygen	Heat Cals.	Compound	Weight
C	.75	1	1823	CO	1.75
C	.375	1	3038	CO_2	1.375
CO	1.75	1	4253	CO_2	2.75
Fe	3.5	1	4106	FeO	4.5
Fe	2.63	1	4231	Fe_3O_4	3.63
Fe	2.33	1	4075	Fe_2O_3	3.33
Mn	3.44	1	5681	MnO	4.44
P	.775	1	4566	P_2O_5	1.775
S	1.00	1	2164	SO_2	2.00
Si	.865	1	6125	SiO_2	1.865
Al	1.125	1	8179	Al_2O_3	2.125
Ca	2.5	1	8219	CaO	3.5
Mg	1.5	1	8963	MgO	2.5

Table figures taken from Richard's "Metallurgical Calculations."

The exact meaning of the figures in the table may be made clear by explaining the method for obtaining the figure for the carbon uniting with an excess of oxygen to form carbon dioxide. The operation of determining this figure is exactly similar to the determination of the heating value of a sample of coal in a bomb calormeter. We cause the reaction to take place between, say, 1 gram of carbon and the necessary amount of oxygen under a high pressure in a heavy steel bomb with the bomb immersed in a measured amount of water. When the carbon is ignited CO_2 gas will be formed explosively at a very high temperature and then will be cooled rapidly by the heavy water-cooled steel bomb. We measure accurately—to the thousandth of a degree if desired—the rise in temperature of the water as soon as the water and bomb are at the same temperature. As 1 calorie is absorbed by each gram of water in being heated 1 degree it is easy to determine just how much heat has been absorbed by the water and the bomb; and this is the equivalent of the heat given off by the reaction, care being taken that no heat is lost or absorbed from other sources during the experiment.

In the above case all the heat given off is utilized to heat the bomb and water in the calorimeter, the quantity of water being taken so large that this change in temperature will be only a very few degrees. The gaseous products of the combustion which at first absorbed this heat gave up the heat and were cooled thereby almost down to the temperature of the carbon and oxygen at starting. In most actual cases of combustion the heat evolved is taken up by the gaseous products of combustion and is transferred from these gases by radiation, contact conduction and in other ways to any material which it is desired to heat thereby, the transfer of heat, however, seldom being 100 per cent efficient.

Heat can be transferred only from a body at a higher temperature to bodies at lower temperatures. The rapidity of transfer of heat from one body to another is greater the more the difference in temperature between the two bodies. A hot body radiating heat to a cooler body is not able to bring the cooler body up to its own temperature because—even if no heat is lost to any other bodies—as the hot body gives off heat it cools, and as the originally cooler body absorbs the heat it becomes hotter, and finally—if no heat is lost—the two bodies will arrive at a common temperature somewhat hotter than the originally cool body and cooler than the originally hot body.

To go back to the figures of our short table we may put their meaning in this way, that if a unit weight of oxygen be caused to react with the weight shown of any other element, both oxygen and element being at laboratory temperature and the resulting oxide be cooled again after the reaction to room temperature, then the tabulated figure shows the heat resulting from the reaction and which can be absorbed in a properly built calorimeter, the products of combustion being cooled therein to the initial temperature of the reacting materials or nearly so. In most cases of practical combustion this is not the amount of heat available from the combustion for the industrial operation, inasmuch as usually the gases formed pass away without being thoroughly cooled and thus giving up the heat evolved in the reaction to the material it is desired to heat. The amount of heat industrially available is only that which can be secured from the gases of combustion by cooling them down as far as may be and transferring the heat to the body we wish to get hot. Obviously it is not possible to cool the gases to a temperature below that which is contained in to heat this body.

The above discussion is introduced at some length in an attempt to bring out clearly the quantitative relations with respect to the development and use of heat in the blast furnace, and particularly as this bears upon the reduction of silicon. In order to abstract oxygen from any oxide it will now be clear that it is necessary to supply the amount of heat shown in the table in order to make that reduction possible, and there must usually also be supplied some other element to unite with the oxygen. This heat must be supplied in addition to the heat that is necessary to maintain the temperature high enough to permit or to cause the reaction. Under these conditions, the reduction will proceed faster, the faster the surplus heat is supplied.

The combustion in the hearth of the furnace is very rapid because of the high temperature and the high pressure, and takes place about in the following fashion: The hot blast meets very hot coke just inside the tuyeres, and as fast as contact is made between oxygen and carbon, carbon dioxide is formed which passes to the inner and higher portions of the hearth, and there meeting with additional coke reacts rapidly to form carbon monoxide. In this way all the oxygen of the blast combines with carbon of the coke to form carbon monoxide and produce an extremely high temperature within a short distance from the tuyeres and throughout the hearth. The coke burned away is replaced by fresh, hot coke settling from above, so that in effect at any instant there is always an excess of coke with respect to the blast. The nitrogen of the blast merely absorbs a part of the heat given off by the combustion and bodily transfers it to the higher levels in the furnace as sensible heat.

Let us study next how the heat produced as above will be absorbed by the descending solid stock and what chemical changes will be caused in this stock by this great heat. To do this we must assume arbitrarily figures for various temperatures, which may or may not be very accurate for any particular case, but will at least form a useful basis for study. We will assume, then, that the blast is heated to 600 deg. C., and that the coke in the hearth has been heated by the previous combustion to 1650 and figure how much heat will be produced by the reaction $C + O = CO$ if the CO formed is supposed to be cooled to 1650. The intermediate stage of the reaction to CO_2 does not need to be considered for the effect is very similar to what would be the case if the reaction were directly to CO, which it is for a considerable part of the burning. The effect of the nitrogen will need to be considered, since the nitrogen affects the temperature reached very materially.

Each unit weight of oxygen will absorb 133 calories in being heated to 600 in the stoves. The .75 unit weight of carbon will contain 528 calories when it is heated to 1650. If we add to these amounts the heat given off by carbon burning to CO at ordinary temperature, i. e.,

$$\begin{array}{r} 133 \\ 528 \\ 1823 \\ \hline 2484 \end{array}$$

We will have the total amount of heat present and that will be absorbed by the 1.75 units of weight of the very hot CO. If this CO gas be cooled to 1650, the temperature assumed in the hearth, the gas itself will retain the amount of heat required to heat it from room temperature to 1650, and only the surplus over this will be available in the hearth for increasing the temperature or for other thermal work. 1.75 units weight of CO will absorb 790 calories in being heated to 1650. This subtracted from the 2484 obtained above, because the CO carries this heat to higher levels in the furnace as sensible heat, will leave 1694 calories produced by the combustion and available in the hearth for each unit weight of oxygen burned. That is, this 1694 calories will be actually absorbed at the instant of combustion by the carbon monoxide and nitrogen, and these gases will thus be raised to a temperature much above 1650, and being hotter than the coke and other surrounding materials, will immediately begin to heat them by contact, radiation, etc.

The above figures neglect the effect of the nitrogen in the blast, which, however, must be considered because of the temperature. The weight ratio of oxygen to nitrogen in air is very nearly 3:10. Three and one-third parts of nitrogen heated to 600 in the stoves will bring in an additional 506 calories; but the same nitrogen is further heated to 1650 along with the carbon monoxide, and the heating from 600 to 1650 will absorb 1011 calories which must be provided from the 1694 calories above calculated. This leaves $1694 - 1011 = 683$ calories available for thermal work at a temperature above 1650 in the hearth. The mixture of 1.75 parts CO and 3 1/3 parts nitrogen rising into higher levels of the furnace at 1650 will carry $790 + 1517 = 2307$ calories as sensible heat.

Not all of the 683 calories of surplus heat above 1650 will be used for heating the descending material; but a considerable portion of it will be absorbed in endothermic chemical reactions. Endothermic reactions are caused to take place by supplying heat to a mixture of material which can thus react, and the reaction will proceed in proportion to the rate at which the excess heat is actually supplied.

Let us now return to our figures for the heats of reaction of the elements with oxygen, and study the reductions in the blast furnace on that basis. In order to make this study very clear as applied to silicon let us take up all the more important reductions in order beginning with the easiest, that of the iron oxides.

It will be observed that the heats of oxidation of iron to its various oxides fall between 4075 and 4231 calories per unit weight of oxygen, and that the heat evolved by

CO burning to CO_2 is slightly greater than any of these figures, viz., 4253 calories. This will explain the net evolution of heat observed in the upper shaft levels of the furnace as a result of reduction of iron oxides by carbon monoxide. The direct reduction of any of the oxides of iron by carbon burning either to CO or to CO_2 is evidently endothermic, since the carbon burning even to CO_2 only yields 3038 calories as against the lowest amount called for by any oxide of iron, viz., 4075 calories. This deficiency of heat is supplied by the heat in the hot gases in the shaft of the furnace to whatever extent the reduction is performed by solid carbon rather than by carbon monoxide.

The greater difficulty in reducing manganese is explained by its greater heat of oxidation. A sufficient surplus of heat at a high enough temperature to cause the manganese to be reduced is not encountered to any appreciable extent above the hearth of the furnace. Even in the hearth an appreciable portion of the manganese present usually escapes reduction and enters the slag.

The sulphur with its low heat of oxidation should be easily reduced, and when in the elementary condition will unite with iron or manganese or lime or other base if such a base with a high affinity for sulphur be present in the elementary condition. Lime is such a base, but its heat of oxidation is very great, and to reduce lime a very considerable surplus of heat must be available to force the strongly endothermic reaction. The heat of reaction between the lime and the sulphur itself assists here very much, and the amount of heat actually needed is not as great as appears from studying the oxide heats alone. The following heats of formation of the sulphides per unit weight of sulphur will assist to explain this matter.

CaS	2947
FeS	750
MnS	1425

The reaction for forming lime sulphide is usually written, the figures immediately beneath the various compounds being the heats of formation for the quantity of compound appearing in the reaction per unit weight.

$$\begin{array}{ccccccccc} FeS & + & CaO & + & C & \longrightarrow & Fe & + & CaS & + & CO \\ 1500 & & 8219 & & & & & & 5894 & & 1823 \end{array}$$

If we add together the heats of formation of FeS and CaO, and subtract from this sum the sum of the heats of formation of CaS and CO, the difference of 2002 calories will be the amount of heat required for this reaction instead of 6396 calories which is the difference in the heats of formation of the oxides of lime and carbon alone. Since sulphur in the above reaction is twice the weight of the oxygen in the same reaction, and the above figure is based on the unit weight of oxygen, it will be seen that the heat absorbed by the reaction per unit weight of sulphur is approximately 1000 calories, which is not a serious drain on the heat supply in the hearth, considering the small amount of sulphur usually actually present.

Silicon has a very high heat of oxidation as compared with iron or manganese, viz., over 6100 calories compared to slightly over 4000 for iron and about 5700 for manganese. The reaction for reduction of silicon is usually written

$$\begin{array}{ccccccc} SiO_2 & + & 2C & \longrightarrow & Si & + & 2CO \\ 6125 & & & & & & 1823 \end{array}$$

6125 calories are absorbed to break up the silica and 1823 are evolved in the formation of CO from the oxygen so set free and carbon of the coke, leaving some 4302 calories to be supplied. Now it is only in the hearth of the furnace that a high enough temperature exists to cause this reaction to take place at all. There is a critical temperature below which it seems not to be possible to reduce silicon by means of carbon; and above this temperature the reaction can occur only so fast as the surplus of heat is supplied which amounts to some 4302 calories per unit weight of oxygen or 4920 calories per unit weight of silicon involved.

This matter of critical temperature for the reduction of silicon is of sufficient importance to emphasize strongly. Below this critical temperature, which is at about 1450 deg. C., if we have both silicon and oxygen together under the proper conditions in an oxidizing atmosphere it seems that the silicon will oxidize in preference to carbon, while if conditions remain the same otherwise but the temperature be raised to above the critical point the carbon will oxidize in preference to silicon. This is observed in a very interesting way in the Bessemer process. When the blow is started the iron is considerably below a steel melting temperature and the silicon burns in the early part of the blow. Because of the high heating power of the oxidation of silicon the temperature would rise to a point where the carbon would burn instead of the silicon and leave a carbon free, high silicon blown metal. The excess heat, however, is used commercially to melt some cold pig or scrap and so hold down the temperature to such a point as to secure the blown metal practically free of both silicon and carbon.

The same facts apply in the blast furnace as in the Bessemer converter, but their application is a little different. When the temperature in the blast furnace is maintained above this critical point then silicon is reduced from silica. We calculated above that the reduction of silicon required 4302 calories per unit weight of oxygen concerned; this corresponds to some 4920 calories required per unit weight of silicon reduced. We also calculated that under certain arbitrary conditions the combustion of carbon to carbon monoxide in the hearth produced a certain surplus of heat, which under the conditions assumed amounted to about 683 calories per unit of oxygen from the blast at a temperature above 1,650. This corresponds to some 910 calories per unit of coke; from which it is clear that the surplus heat production from some 5.4 units of weight of coke is required for the heat absorbed in the reduction of 1 unit of weight of silicon. This is probably fairly close to the amount of coke actually required in the furnace for this purpose.

The other conditions which affect the reduction of silicon are the amount of slagging bases in comparison to the amount of silica, and the amount of silicon in the iron. The silicon unites with some of the iron to form the compound FeSi which dissolves in the iron. The heat of this reaction and solution is probably not very great but it assists slightly towards the reduction of silicon from silica. The heat of solution of silicon in iron decreases rapidly as the amount of silicon in the iron increases. This and other factors act to make it increasingly difficult to secure an added unit of silicon in the iron as the amount of silicon already in the iron is greater. A basic slag tends to hold silica as such much more strongly than an acid slag.

One of the important means by which the temperature of the blast furnace hearth is maintained at a high level is by means of slag composition, viz., by keeping the mixture of slag forming materials such that it will not fuse down into a limpid liquid except at a high temperature. The result of this is to hold the material in the stream of superheated gases a longer time until it does attain the higher temperature necessary for fusion. While the material is thus held at the high heat and in the presence of carbon monoxide and in contact with coke the conditions are attained which are needed to reduce silicon.

The reactions outlined oppose each other to some extent. As silicon is reduced less silica is left for the lime and other bases, and the slag becomes less fusible. But as this action increases the affinity of the more basic slag for silica increases and it becomes more difficult to reduce further silica. The various reactions proceed toward the equilibrium conditions as far as time permits. That is, each particle of silica settling through the hot zone of the furnace is exposed to the action of the hot carbon, carbon monoxide, lime and other materials. It will go through as silica or be reduced to silicon according to which influence is the stronger and about in proportion to how much stronger that influence is.

If the blast furnace manager desires more silicon in his iron he will proportion the charge mixture to get more silica. He will adjust the amount of limestone so as to form a slag with the silica to be left as such which slag can be expected to have the right fusion temperature. He will regulate the blast temperature to assist in giving the high temperature desired in the hearth; and he will further watch carefully the operation of the furnace in general to secure that uniformity of running which is essential for a commercial furnace.

Electric Brakes For Steel Mills

It Is More Desirable Practice to Retard and Stop Loads Electrically by Dynamic Braking and to Utilize the Friction Brake Largely for Holding.

By **GORDON FOX***

An electric brake is a friction grip which is set by mechanical means and released electrically. Some brakes are set by gravity through the medium of a weight attached to a lever arm, others are set by springs. Release is ordinarily accomplished by an electric magnet or solenoid, but a small motor is sometimes employed. Most brakes are applied to an extension to the armature shaft as being the most effective point.

The function of an electric brake may be either to retard and stop a motor and machine, to hold a machine at rest against a force or both to stop and to hold. A brake must be dependable because, if it fails, life may be jeopardized or property seriously damaged. It must therefore have a high safety factor.

Brakes may be classified according to their mechanical design. The common types are, the band brake, the disc brake and the shoe type or post type brake. Brakes may also be classified according to their use on direct current or alternating current systems.

The band brake is a familiar type, consisting of a flexible band encircling the brake wheel. This band is lined with a woven friction material or with wood or composition friction blocks. The band is usually anchored at one end. The other end is drawn tight by a weight or spring which, in turn is released by the solenoid. The band brake is a simple type. It has the advantage of large friction area as nearly the entire wheel circumference is encircled. It serves very well as a holding brake particularly against a force always in one direction. A band brake exerts more torque in the wrapping than in the unwrapping direction of rotation, the latter being one-third to one-half the former. A band brake causes a side thrust to be exerted on the shaft as the pull is largely in one direction. It is somewhat difficult to maintain clearance at all points around the brake wheel due to slight eccentricity and irregularity in the band, hence the opening movement must be considerable. Band brakes are commonly operated by solenoids having a fairly long travel. These solenoids may be actuated by either direct or alternating current.

The disc type brake consists of a series of nonrotable plates or stages alternating with a series of rotating plates. The stationary plates are machined surfaces. The rotating plates are loosely keyed to a hub mounted on or connected to the motor shaft. They are lined on both sides with friction material. The stationary and rotating plates are pressed together by a spring and are released and separated by a magnet. Fig. 1 shows a brake of this type attached directly to a crane motor.

The principal advantages of the disc type of brake are its compact construction, its relatively light weight and its quick action. This type of brake requires very little room perpendicular to the shaft and little head room. It has little inertia due to the light weight of its revolving parts. It has a large wearing surface area. It is at a disadvantage in that the brake must be moved or dismantled in removing an armature. It is a little more difficult of alignment. It cannot readily be released by hand. The friction surfaces are enclosed, are somewhat inaccessible for inspection or repair and the heat dissipating ability is restricted. Ventilation is provided to minimize this difficulty. The enclosure of the friction surfaces protects them from oil and from the weather. The disc brake can be mounted on the end of a shaft only. It cannot be well adapted for alternating current.

The shoe type brake is probably the most commonly used. It consists of a brake wheel and two shoes

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which are attached to levers. The shoes are made to clamp the wheel, either by weights or springs acting on the levers. In some types there is a more or less complicated linkage of levers. The shoes are released either by a solenoid or by a magnet acting through the levers.

The shoe type brake is both rugged and accessible. It introduces no end thrust or side thrust. It is usually attached to the armature shaft extension but may be attached to a central portion of a shaft. This type of brake may be arranged to permit easy removal of the armature. Shoes brakes are commonly 30 to 40 per cent heavier than band or disc types. They require a comparatively powerful solenoid. They have a minimum area of wearing surface. The friction surfaces are exposed to the weather. Some designs are rather bulky and require considerable space alongside and head room above the motor.

There are many designs of shoe type brakes differing considerably in their principal features. Fig. 2 shows a brake which is set by gravity and released by a solenoid. This type of brake is well adapted for use with a dash pot. Cut out devices mentioned later may be readily applied. The coil is enclosed and fully protected.

There is considerable inertia in the moving members in a gravity actuated brake, tending to delay initial movement and tending to cause rather sudden clamping action. In any solenoid brake there is some magnetic lag and there may be friction between the plunger and the bore of the solenoid. Fig. 2 shows a shoe brake which is actuated by springs, a magnet being used instead of a solenoid.

A large number of levers in a brake mechanism is undesirable because of complexity and there is more or less wear at the hinge pins depending upon the amount of pressure and movement. This leads to friction and lost motion. Fig. 4 shows a simple shoe type brake employing a minimum of parts. The brake is set by a spring enclosed within the magnet housing. It is released by a large, short stroke magnet. This brake is exceptionally compact, and requires little head room. The short stroke affords quick action and the comparative absence of inertia eliminates shock on setting or hammer on release. The brake can be easily dismantled for removal of the armature without affecting its adjustment. The magnet coil is enclosed and protected. This brake is adapted for direct current only.

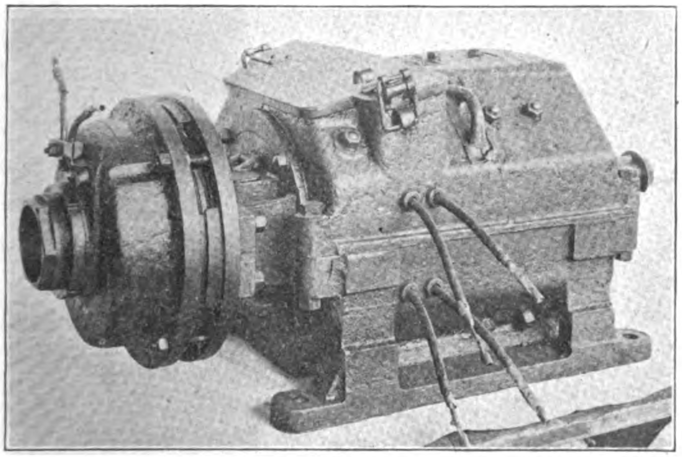

Fig. 1—Disc brake attached to crane motor.

The majority of direct current brakes are wound with relatively few turns of heavy wire and arranged for connection in series with the motor. The most obvious reason lies in the fact that a coil thus connected is automatically deenergized and the brake released when the current is shut off. There are other contributing causes for preference of a series brake where applicable. In the case of a crane, an extra trolley bar and collector would be required if a shunt brake were used. With a series brake there is definite assurance that when the brake is released the motor has current to hold the load. A shunt brake might be released even with the armature circuit open and no holding torque developed. The coil of a series brake contains fewer turns of relatively large wire and is therefore more rugged and dependable. The series wound solenoid acts more quickly than the shunt coil in releasing and setting the brake.

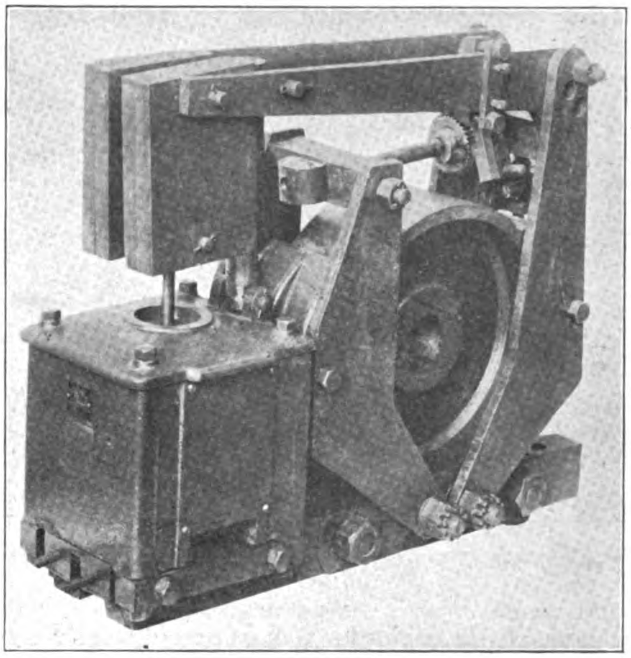

Fig. 2—Shoe type brake, gravity set and solenoid release.

On the other hand, there are many applications where the use of the shunt wound brake is necessary or preferable. In elevator service and mine hoist service the armature current may pass through zero and flow in either direction depending upon whether the motor hoists or retards. A series brake could not be held open. In the case of a crane hoist, the brake is ordinarily connected in series with the series field in lowering. If a high lowering speed is desired it is necessary to weaken the series field to a point such that the current passed in this circuit would not hold open a series brake. Shunt brakes are therefore frequently used for the hoists of coal and ore bridges, skull crackers and similar service. It is often desirable to have a drift point on a control. Obviously this is feasible with a shunt brake only as this may be maintained energized. Crane bridges are sometimes thus equipped, also lift bridges. The shunt brake also has some advantage in that its energizing circuit may be handled by a small contactor which may be interlocked with protective features. The advantage of the series brake lies in simplicity of action. The advantage of the shunt brake lies in flexibility of application.

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The point has been raised that a shunt wound brake tends to be more sluggish than a series brake. This is due to the inductance of the shunt coil which retards the building up and dying out of the flux. In order to alleviate this condition some shunt coils, particularly for the larger brakes, are sometimes wound for half voltage and connected in series with resistance. This permits a high current inrush and gives quick release. In some cases the sluggish action is desirable. Compound wound brakes are not uncommon. The series coil is usually in circuit for a short period to give quick release. It is then short circuited by the control, having a comparatively light shunt winding to hold the brake released.

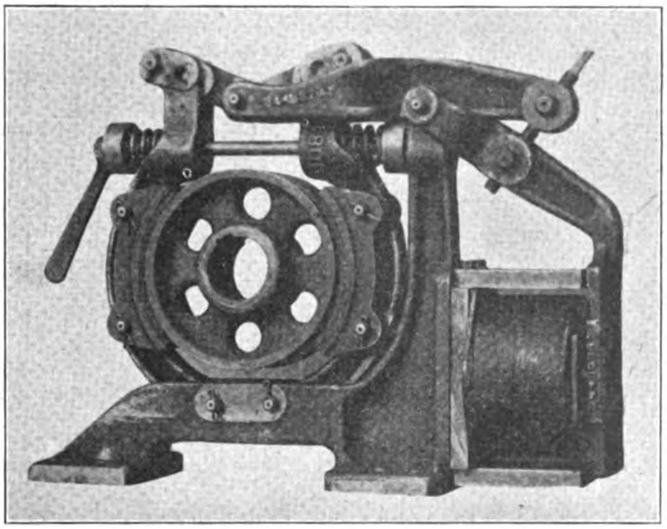

Fig. 3—Shoe type brake, spring set and magnet release.

The alternating current magnet is not as well adapted for brake duty as the direct current magnet. A relatively bulky laminated construction is necessary to limit iron losses and heating. The current in a single phase coil passes through zero every cycle. Shading coils are employed to carry the magnetism over these periods. However some tendency to chattering is liable. Some brakes are supplied with three phase coils, overcoming this difficulty. These however are relatively bulky and complex.

The solenoids for alternating current brakes are sometimes made oil immersed to minimize chattering and noise and also to act as a dash pot. This construction is particularly applicable for elevator service.

Alternating current brake solenoids are all shunt connected. The pull of the solenoid varies decidedly with the voltage. Taps are sometimes supplied so that the coil may be adapted to conditions. The current in a direct current coil depends on resistance and is independent of the air gap. The current in an alternating current coil is limited by impedance, mostly reactance. The longer the air gap the less the flux and the lower the reactance. The current is a minimum when the air gap is closed and is much higher when the gap is open. When voltage is applied a high current inrush occurs, the current falling off as the air gap closes. In operating an alternating current solenoid it is necessary to see that the moving core pulls up promptly, else the current will be excessive and will probably burn out the coil. As the gap is allowed to close entirely and seal, there is a possibility for this type of brake to hold open due to residual magnetism. Fig. 5 shows an alternating current shoe type brake in which a motor is employed instead of a solenoid for releasing. The brake is set by a spring. The motor drives through a pinion and toothed sector to which a lever is attached. The motor exerts torque to release and hold open the brake. The motor is a special high resistance cage type induction motor designed to withstand stalling. The motor is equipped with a combination slip gear and mechanical brake device which cushions its action. This type of brake is quiet in action as vibration and chattering are eliminated. The shoes are applied without shock and released without pounding. No dash pot is required. There is no initial current inrush and possible coil burnouts are avoided.

There are usually three adjustments to a solenoid or magnet operated brake. These are adjustment for shoe clearance, for braking intensity and for air gap. It is necessary to adjust the shoes for equal clearance and equal braking effect without side thrust. The braking intensity is adjusted by change in the amount or leverage of the weights, by changes in the lever linkage or by adjustment of the compression of the springs, as the case may be. It is desirable to maintain a definite air gap at the solenoid or magnet in order to obtain the required pull. The air gap should be the minimum amount which will give sufficient movement to release the wheel fully. The proper adjustment of the magnet, on direct current, affords the strongest obtainable magnet pull, thus permitting maximum braking intensity adjustment and giving prompt and definite action. In the case of alternating current proper adjustment helps to prevent excessive current inrush due to wide air gap.

It has been mentioned that some types of brakes are more sluggish in action than others. This is not always an undesirable feature. What is desired is prompt release without a hammer blow caused by sudden stoppage of the moving parts, together with prompt but gradual setting. Some brakes tend to grip suddenly and cause a shock to the load and the transmission gearing. It is evident that minimum inertia in the moving parts is desirable to these ends. In this respect the use of compression springs had advantage over weights. In some brakes either an air or oil dash pot is supplied to cushion the action, and

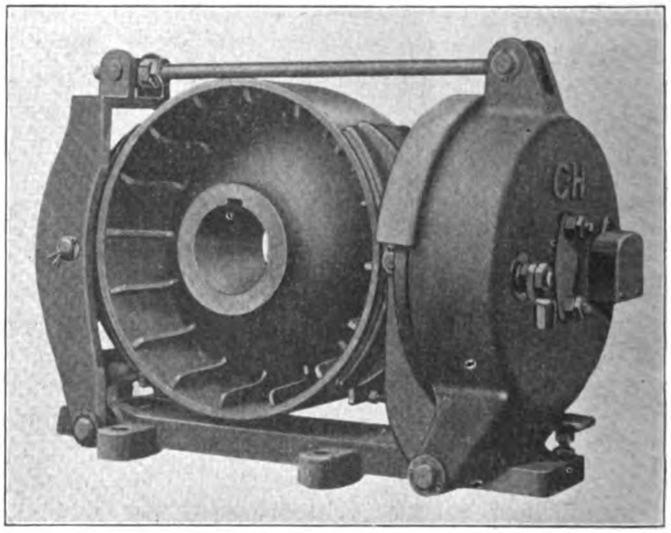

Fig. 4—Shoe type brake, spring set, magnet release.

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prevent too sudden application. In a few cases, in connection with shunt wound brakes, electrical means are employed to delay the action. This may be done by shunting the brake coil with a discharge resistance. The stored energy in the coil causes a current to flow through the discharge resistance when the coil circuit is opened. This discharge current delays and cushions the setting of the brake. A short circuited damping winding will have a similar effect. Totally enclosed "ironclad" solenoids have this effect to a limited extent due to the eddy currents in the iron when the magnetism is established or interrupted. The motor released brake is damped to some extent by the inertia of the rotor of the small releasing motor.

Brakes are more commonly mounted separately on the motor bed plate. Frequently, however, they are attached to the motor. Motor mounted brakes require finished pads on the motor and, in some cases, special parts for adaption. Most crane and hoist motors are provided with brake pads. The advantage of motor mounting lies in the self contained unit with no alignment difficulties and no special base construction. The disadvantages are less firm and substantial construction and less easy dismantling. Motor mounted brakes are usually of the disc type.

Brakes are rated in lb. ft. of retarding torque which they will develop at the brake wheel shaft, as referred to revolving wheel condition. As the coefficient of static friction is higher, the holding torque is somewhat greater than the retarding torque. The holding torque is ordinarily about 110 per cent of the retarding torque. The retarding torque which a brake will develop depends materially upon the amount of weight or the extent to which it is "set up." This in turn depends upon the strength and ability of the solenoid or magnet to release. Where an intermittent duty coil is used, it may be worked harder and made more powerful. Therefore the brake may be set up tighter and its retarding torque rating increased.

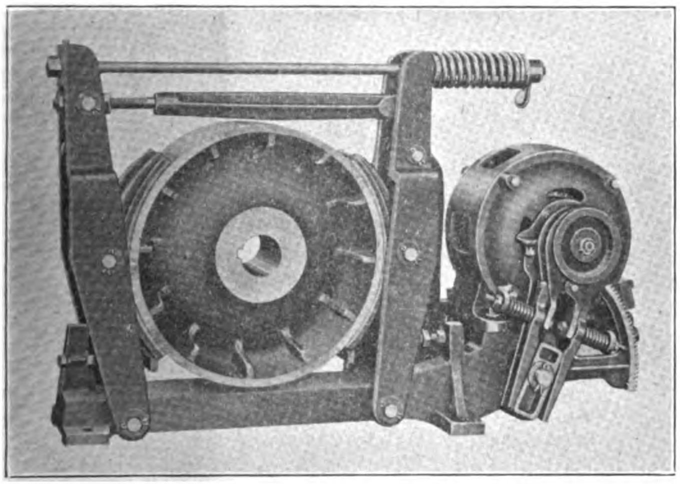

Fig. 5—Spring set, motor released brake for alternating current service.

It is evident that a brake retarding a given torque from high speed will dissipate more energy than one retarding the same torque at low speed. The ability of a brake to dissipate the mechanical energy which is converted into heat, is one of its limitations. Brakes are therefore given a maximum hp rating which signifies the highest hp motor with which the brake may be expected, under average conditions, to function without undue heating and with reasonable shoe wear.

The coil of a series brake carries motor current and must be proportioned accordingly. Brakes are rated in the same manner as the motors with which they are used, the common ratings being on a 30 minute or 60 minute basis for intermittent duty and a continuous duty rating. The intermittent duty brakes will release on 40 per cent rated current. Continuous duty brakes will release on 80 per cent rated current. Series brakes, once released will hold open down to about 10 per cent of rated current. It is desirable in crane hoist dynamic lowering that the brake release on 40 per cent full load current or less. The brake should open on the first point lowering.

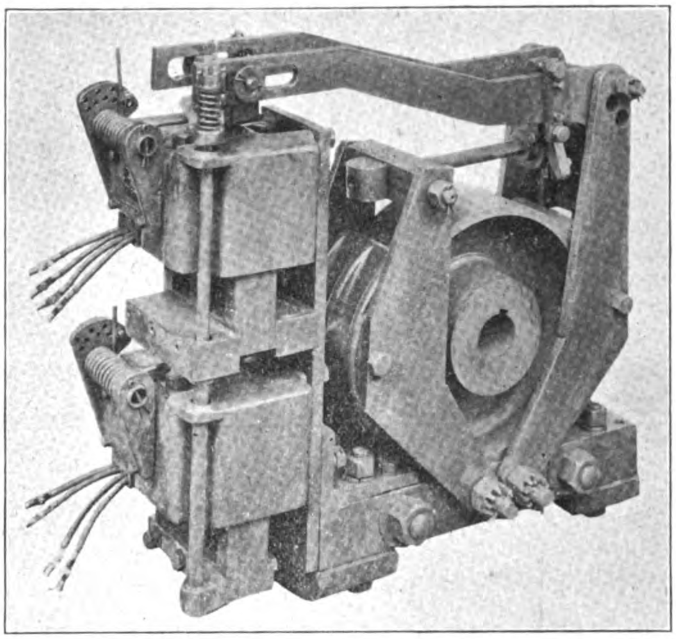

Fig. 6—Alternating current brake providing graduated braking effort.

Shunt wound brakes are given either a continuous duty or an intermittent duty rating. The coils of some brakes are wound for less than rated voltage. The coil is connected across the line to release the brake. Movement of the brake members actuates a small switch which causes resistance to be inserted in series with the brake coil. The reduced current is sufficient to hold the brake released but minimizes the coil heating.

Brakes are selected on the basis of torque. The full load torque of a motor may be determined by the formula—

$$T = \frac{5250 \times HP}{RPM}$$

Where T = torque in lb. ft.
HP = full load HP rating of motor.
RPM = speed of brake wheel.

Ordinarily a brake is selected having a retarding torque equal to full load motor torque. Sometimes a lesser torque will suffice and sometimes a higher torque, such as one and one-half times full load torque is thought desirable either to gain a very quick stop, to hold an occasional heavy load or to provide a safety factor, particularly as to adjustment and condition.

Where service is particularly severe or continuous

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the heat dissipating ability of the brake becomes a governing factor and it is necessary to select a brake on the basis of its limiting hp rating rather than its torque. The limiting temperature which lining materials will stand is about 200 degrees C. It may be well, at this point, to state that hard lining materials are desirable as they will retain adjustment better. Soft linings give more friction but they wear faster and compress.

For high speed work it is necessary to check the peripheral speed of the brake wheel.

The brakes which have been thus far described and discussed are of a type which are either fully set or fully released, as the case may be. There has been recently developed a brake for use on alternating currents which affords graduated braking. This brake is adapted for crane hoist service. It is similar in general construction to the ordinary shoe type solenoid brake. It has, however, two solenoids. One of these is connected across primary voltage and is energized only while hoisting and on the lowering points where regenerative braking is used. At standstill and on some lowering points this solenoid is deenergized. The second solenoid is connected across a phase of the rotor of the motor. When both solenoids are deenergized, as at standstill, full braking torque is obtained. In hoisting, the two solenoids function together to release the brake. In lowering, the second solenoid governs. When this solenoid is energized, the braking torque is relieved in proportion. As this solenoid is across rotor voltage, the higher the lowering speed, the less the slip and the lower the rotor voltage, hence the greater the braking torque. The brake thus automatically adapts its effort toward controlling the speed. Fig. 6 shows a brake of this type.

Electric brakes find a wide field of application. Cranes, hoists and elevators are probably the greatest field. Steel mill auxiliaries often require brakes. Lift bridges are so equipped. There are many miscellaneous applications.

In closing it may be stated in general as more desirable practice to retard and stop loads electrically by dynamic braking and to utilize the friction brake largely for holding. This practice minimizes the wear on the brakes, decreases their maintenance and insures with greater certainty their good condition for their important holding duty. There are, of course, many exceptions where this added complication may not be warranted.

Tropenas Converter For Making Steel

General Description of This Process, Details of the Converter and Information Regarding the Cupola Change—This Process Is Very Similar to the Bessemer Process.

By S. R. ROBINSON

THE original method of blowing steel was invented by Sir Henry Bessemer in 1856 in Sheffield, England. Bessemer thought that his patents covered every method of blowing steel, however, some years later Mr. Tropenas obtained a patent which covered the introduction of air onto the surface of the metal and supplemented this with an additional row of pipes or "tuyeres" which supplied additional air to convert any carbon monoxide (CO) to carbon dioxide (CO_2) that was not fully burnt by the lower row of tuyeres. The upper tuyeres were later discarded, having been found unnecessary.

By this process, there was less agitation of the bath, less power was required for blowing and the process was in every way better adapted for small heats from one to three tons.

The Tropenas process consists in melting a mixture of low phos. pig iron and steel scrap in an ordinary cupola, transferring this metal to a converter in which a blast of air is allowed to impinge onto the surface of the metal. The blast of air furnishes oxygen which unites with the silicon, manganese and carbon in the iron forming respectively Silica (SiO_2), manganese dioxide (MnO_2), and carbon monoxide (CO), and carbon dioxide (CO_2). Some iron is also oxidized forming F_2O_3. The silica, manganese oxide and iron oxide unite to form a slag consisting of silicates of iron and manganese, while the carbonic oxide goes off as a gas.

This reaction generates an intense heat which raises the temperature of the metal several hundred degrees and actually converts the iron into steel. When the "blow" is finished, which is indicated by the sudden dropping of the flame, we have a bath of metal containing about .08 per cent to .10 per cent C. and traces of manganese and silicon. The bath is then "recarbonized" by the addition of cold pig iron or more commonly a small amount of liquid cupola iron; the bath is then "deoxidized" by the addition of melted or lump ferro manganese (80 per cent Mn) and ferro silicon (50 per cent Si) so that the composition of the metal for soft or medium carbon steel shall be carbon .25 per cent to .30 per cent, manganese .60 per cent to .75 per cent, silicon .30 per cent to .35 per cent. A small amount of metallic aluminum is always added to the metal as a final deoxidizer—about 6 oz. to the ton. The metal is then poured into molds. By this process, there is no attempt made to lower the phosphorus and sulphur. It is an "acid" process, that is, the lining of the vessel is of an acid nature, namely, silica. Owing to this fact, the raw material must be as low as possible in phos. and sulphur. The low phosphorus pig iron should not contain over .04 per cent phos. or sulphur and the steel scrap if it is bought outside should be kept below .04 per cent in phos. and sulphur also if possible.

The Converter.

The writer will describe the vessel of 2 tons capacity, as he is more familiar with that size than the one ton vessel. The body of the converter is a cylindrical shell made up of boiler plate approximately ½-inch thick, riveted, with a cone shaped bottom also riveted to the shell, and a dome shaped top bolted or keyed to the top of shell. See attached sketch for inside dimensions. Some of the later vessels have a flat bottom, in halves, hinged, similar to a cupola. The bottom is dropped to allow the vessel to cool off quickly for repairs.

The "tuyeres" through which the air is admitted to the bath are of the utmost importance, for it is upon them that the entire operation depends. They should at all times be perfectly level and in line with each other and kept at the proper size. They can be made in three ways: first, special brick with a one and one-quarter inch diameter hole can be used. These brick are usually made of fire clay and are not very satisfactory. Second, ganister can be rammed around one and one-quarter inch pipe or rods and these pipe later withdrawn. This is the usual practice. Third, one and one-quarter inch inside diameter pipe can be rammed up in place and allowed to remain in the lining and used as "tuyeres." This method requires careful attention on the part of the operator, for if any hot metal lodges in the pipe, it is difficult to remove.

With proper attention, the latter method is the best. Seven tuyeres are used in the 2-ton converter. The converter is lined either with silica brick or rammed ganister. The best practice is to line with silica brick and patch with ganister. After lining, a coke fire is used to dry out the lining for about 24 hours. About two hours before the iron is ready to be poured into the converter, an oil burner is inserted through the central tuyere and the vessel heated with the oil flame supplemented with air from the positive pressure blower for more complete combustion. Before starting the oil flame, the converter is first emptied of all unburnt coke and ashes.

As soon as sufficient iron has been melted in the cupola, say 4,000 lbs., this iron is taken to the converter by the crane and poured into the converter. Just previous to this, the oil burner has been removed from the converter and the air shut off. As soon as all the iron has been poured into the converter, the operator or "blower" takes his station at the back of the converter and signals for the converter man to tip the vessel back. The blower puts on his blue glasses and looks through the tuyeres while the vessel is being slowly tipped back. As soon as the metal comes up to the bottom side of the tuyere hole, he stops the vessel. The metal should come almost but not quite in the tuyeres. The vessel should now be standing at an angle of from 6 to 10 degrees from the vertical—7 degrees is the best angle for blowing. If the angle is greater than that, some iron must be poured out of the converter; if the angle is less than six degrees, more iron must be put in the converter. The numbers of degrees is shown on a dial placed at the side of the converter. When the proper amount of iron has been put in the converter and the tuyeres are set correctly, the blast is turned on from the positive pressure blower. This blower should be of a proper size to deliver air at a pressure of from 2¾ lbs. to 3¼ lbs. to the square inch through the seven one and one-quarter inch tuyeres. This requires a No. 4 Root or Wilbraham-Green Blower.

This pressure of 3¾ lbs. to 3 lbs. is at once put on the converter. At once sparks and smoke are emitted from the mouth of the converter gradually increasing in volume until at the end of from 3 to 5 minutes a flame shows at the mouth of the vessel. This flame gradually increases in intensity until at the end of from 10 to 12 minutes from the start of the blow the "boil" commences, at which time the pressure must be reduced in order to prevent metal from being thrown out of the vessel. The "boil" continues for from one to three minutes the flame increases in size and the air pressure is again increased to about 2¾ lbs. The blowing is continued for about 8 minutes when the flame again increases in size but with less tendency for the metal to be thrown out of the vessel. The flame after about one minute suddenly "drops" or becomes shorter by one-third which marks the end of the blow. The converter is then "turned down" as rapidly as possible and the air shut off. The bath is now ready for the deoxidizers. The ferro manganese may be added cold in lump form by wetting the lumps and throwing them into the bath or this alloy may be broken up into small pieces and thrown into the ladle while the metal is running in, or the alloy may be ground fine and preheated in the ladle and the metal poured onto it. The ferro silicon using the 50 per cent alloy is put in the ladle. Aluminum is also added. Points to be watched in blowing:

As soon as the carbon flame shows, the vessel must be tipped back toward the vertical about 2 degrees. The first stage of the blow from the time the air is put on until the carbon flame shows, is the period of great importance. During this time, the silicon is being burnt or oxidized from silicon to silica (Si plus O_2 equals $S:O_2$), and also the manganese and some iron, but these are of less importance, as heat producers than the silicon. Bear this point always in mind: **The silicon is the heat producer in the converter process.**

If the melted iron from the cupola is deficient in silicon, regardless of the temperature of this iron, the blow will come cold unless additional silicon is added during the blow. The silicon content of the cupola iron should be about 1.8 per cent. The first period of the blow should last from 3 to 5 minutes. If less than 3 minutes, additional silicon should be added at once by throwing into the converter lump 50 per cent ferro silicon usually about 20 pounds.

If the first period is longer than five minutes, the silicon is too high and a "sloppy" "wild" blow will usually result. This can be corrected in subsequent blows by lowering the silicon in the charge. The length of the first period is, of course, dependent on the proper setting of the tuyeres. As a rule, before starting to set the tuyeres, the vessel should be turned down to a horizontal position and the metal thoroughly skimmed. Then set the vessel so that the metal shows just at the under side of the tuyeres. If this is done properly, the above remarks in regard to the length of time of the first period will hold good.

The Cupola Charge.

The charge is made up of low phosphur pig iron and steel scrap, from 30 per cent to 50 per cent steel scrap is used. The charge is figured so that the silicon in the melted iron will be 1.80 per cent Si. allowing .25 per cent loss of silicon in melting. Thus: Suppose the pig iron contains 3.25 per cent silicon and the steel scrap .25 per cent silicon, then a charge of 1,000 lbs. of the mixture will contain 600 lbs. pig iron and 400 lbs. steel scrap. 600×3.25 equals 19.5 lbs. silicon.

400×.25 equals 1.0 lbs. silicon.

Total 20.5 lbs. silicon.

Then 20.5 × 100 equals 2.05 per cent silicon going into cupola. Allowing .25 per cent loss, we have 2.05 — .25 equals 1.80 per cent silicon coming out of cupola.

Final additions:

Ferro manganese if used in the ladle.

It will require about 20 lbs. of the 80 per cent alloy to the ton to give .70 per cent Mn in the steel.

It will require about 12 lbs. to the ton of 50 per cent ferro silicon to give .30 per cent silicon in the steel.

Costs:

Assuming low phos. pig at	$40.00	ton
Own steel scrap	35.00	ton
Outside steel scrap	12.00	ton
Ferro manganese	60.00	ton
Ferro silicon	60.00	ton
Coke	6.00	ton

Assume charge of 60 per cent pig iron and 40 per cent steel scrap. Assume a combined cupola and converter melting loss of 18 per cent.

Then:

Cost of 1,200 lbs. pig iron equals	$21.43
Cost of 800 lbs. steel scrap equals	9.40
Total	$30.83
Allowing 18 per cent loss, cost per ton	$36.38
Cost of 20 lbs. ferro manganese equals	.60
Cost of 12 lbs. ferro silicon equals	.36
Cost of 300 lbs. coke	.90
Cost of repairs	1.00
Cost per ton steel in ladle exclusive labor	$39.24

Breakage of Rolls on Sheet and Tin Mills

A General Discussion on the Characteristics of Sheet and Tin Mill Rolls Showing the Causes for Breakage and How to Avoid Them.

By W. H. MELANEY

PART I

A GREAT deal of mystery has always been associated with the breakage of rolls on Sheet and Tin Mills and very few mill managers attribute it to exactly the same cause.

All of them will agree that heat is the most prolific source of the trouble, but few of them ever try to reason out why this is true, and fewer still seem to realize the small amount of heat that is required to produce disastrous results under certain conditions.

In order to get a clear understanding of conditions, it will be necessary to first consider the composition of and method of casting these rolls, and the radical difference in structure between the rolling surface of the roll and the mass of metal that composes its interior and just what happens when these two very different structures are suddenly heated.

It is true of course, that the chemical composition of both structures are approximately the same, as they are both poured from the same ladle of metal. But due to the conditions under which they are cooled down to the temperature at which the metal sets or assumes the non-fluid state, there will necessarily be a slight difference in the proportions of the various elements that go to make up the whole mass, especially in the carbons.

Casting a Chilled Roll.

All chilled rolls are cast in an upright position. The mold being of a composite structure, as shown at (Fig. 1), in which the rolling surface of the roll is cast in a heavy cast iron mold, and the necks and wabblers in sand.

Characteristics of Chill Irons.

It is a characteristic of cast iron of the composition of which chilled rolls are made, that if it is suddenly cooled from its molten state below the temperature at which it sets or becomes a solid mass, that the portion so cooled will assume a crystalline form.

This is due to the carbon which is all believed to be in the combined form when iron is in a molten state. If there is no element in excess, such as silicon or manganese, to force it out of combination in cooling by permitting it to change from combined or crystalline carbon, to that of graphitic carbon, then when the molten iron is suddenly cooled, the carbon will practically all remain in the combined or crystalline form. Therefore, in casting a chilled roll, that portion of the mass that can be so suddenly cooled will retain its crystalline form and become a solid white mass, as hard as hardened steel with its crystals at right angles to the chilling surface, while the metal contiguous to it for a certain depth, will be of a speckeled or sprayed appearance, partly crystalline and partly granular, as a part of its carbon, due to slower cooling, will precipitate out into the form of graphitic carbon, thus causing this sprayed appearance.

This sprayed portion will, in an ideal mixture, be approximately of the same depth as the white hard crystalline portion, while all of the rest of the mass of metal down to the center of the roll, will be ganular. The still slower cooling permitting most of its carbon to assume the graphitic form and as graphite is almost black in color, this part of the roll will be of a dark gray color, in sharp contrast to the white chilled portion or the light gray sprayed portion. The white crystalline portion known as the chill on sheet or tin mill rolls, will vary from ½ in. to ¾ in. deep. The longer rolls having the lighter depth of chill.

Form of Mold.

(Fig. 1) is a sectional view of a mold, such as a chilled roll is cast in.

The lower portion "A" consisting of an iron flask rammed with molding sand which contains the lower neck and wabbler of the roll. The middle portion "B" is a thick cast iron cylinder, bored out to suit the diameter of rolls wanted and in which the body of the roll is cast. The top portion "C" also an iron flask rammed with sand and containing the top neck and wabbler, as well as the sinking head.

The sinking head is used to prevent piping or hollowness in the top wabbler, by feeding liquid metal to this portion as the roll slowly cools, and is later cut off when the roll is turned to size.

When this mold is filled with molten cast iron of the proper chemical composition, that portion in contact with the iron cylinder "B" is rapidly cooled as iron being a good conductor of heat, absorbs and radiates the heat of the molten metal in contact with it until its setting point is reached, and which only requires a few seconds.

The result is a crystalline mass of white hard chill of a given depth, depending upon the chemical composition of the mixture.

The sprayed portion being due to the tapering off of the cooling action as this metal is out of contact with the chilling action of the cylinder "B"

The dark gray mass beyond the sprayed portion being still further away from the chilling action, is permitted to cool gradually thus permitting the bulk of the carbon to assume the graphitic form and produce a granular structure. The molten metal in those portions of the mold which are rammed up with sand, due to sand being a very poor conductor of heat, cools so slowly that even the surface shows no crystalline nature and is all of a dark comparatively soft granular structure, the same as the center of the roll.

Physical Characteristics of the Roll.

A little reasoning will prove to you that here you have a composite structure in the resulting roll showing at least three clearly defined physical characteristics.

A white hard portion, say ¾ in. deep with a total shrinkage of ¼ in. to the foot and which expands rapidly on heating.

A sprayed portion of approximately the same depth with a slower rate of shrinkage approximately 3/16 in. to the foot and expanding slower than the white hard portion. And a dark gray mass in all the rest of the roll of a granular structure with only ⅛ in. contraction to the foot, and having a still slower rate of expansion on being heated. All three of these characteristics being assembled in one inseparable heterogeneous mass.

It requires very little thought to convince yourself that if the outer surface of the roll with a contraction practically double that of the inside mass did not get most of its contraction while the inside was still fluid, that it would tear itself apart in cooling, during the casting process, and this sometimes happens.

Also that the casting strains would wreck it but this is taken care of by prolonging the final cooling of the roll over a long period of time to permit the molecules to gradually re-arrange themselves.

The chilled surface due to contraction soon gets out of contact with its iron mold, which also due to the absorbtion of heat rapidly expands and increases the distance between it and the chilled surface of the roll with the result that this chilled portion is gradually raised in temperature, by the molten metal of the interior, permitting a certain amount of annealing action to take place, thus relieving the casting strain.

Preparing the Rolls for Rolling Sheets.

After the rolls have been turned they are placed in the mill housings preparatory to rolling sheets. Finishing rolls of this type are of necessity used hot and a final working temperature of 750 degrees F. has been found to give the best results in practice, but if this temperature was permitted to extend into the necks, it would be found impossible to keep the necks lubricated, as the lubricating grease would catch fire and burn up, leaving the necks dry. Therefore, a small amount of water is permitted to trickle over the neck or wabbler to absorb a part of this heat and keep the necks cool enough for proper lubrication but no water is permitted to touch the rolling surface of the roll. The temperature of the ends of the roll being regulated by the water on the necks.

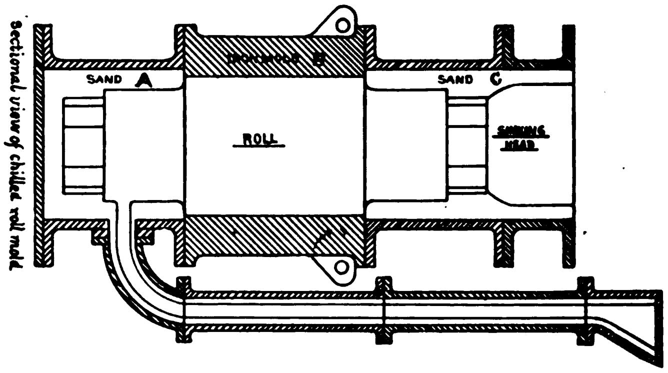


Fig. 1.

Concaving Rolls.

The center of the rolling face of a roll is always the hottest point when in service, due to the ends of the rolls having a portion of their heat radiated out through the necks and wabblers. The center of the rolls being almost twice as hot as the ends.

This causes the center of the rolls to puff up and the surface would become convex if some means were not employed to prevent it. A perfectly flat surface or one in which the surface of the rolls are in contact over the entire working face, is desired, as under these conditions only can wide sheets be rolled.

This condition is easiest produced by turning in the face of either one or both rolls a concavity equal to the amount of convexity that would otherwise result.

When the rolls are at proper working temperature, this concavity disappears, due to the puffing up of the center of the rolls from expansion by heat. The trick being to keep this puffing up under complete control so that it is neither too great nor too little to give the rolls an even bearing along their rolling face.

The usual method of control being the blowing of air or steam upon the center of the rolls to regulate the expansion, as even the temperature of dry steam is much below the working temperature of the rolls and will rapidly reduce their heat, thus preventing their puffing up too much in the center.

Heating the Rolls for Service.

As rolls when first placed in service are of a temperature corresponding to that of the surrounding air, it is evident that due to the concavity previously turned in them, they would only be in contact on each end of the roll, see (Fig. 2), and as this condition would prohibit the rolling of sheets of even gauge over their entire width, it becomes necessary to first heat the rolls in order to puff up the middle until this concavity disappears, (see Fig. 3), before wide sheets can be rolled on them.

Causes of Breakage.

Right here is where all the trouble starts as very few of the operatives seem to realize the extreme sensitiveness of these rolls to heat conditions, and what is really taking place during this warming up process, or how little heat is sufficient when quickly applied, to tear the rolls apart.

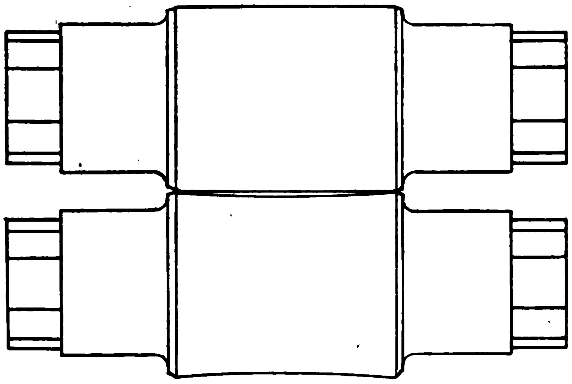

showing concave in rolls before heating

Fig. 2.

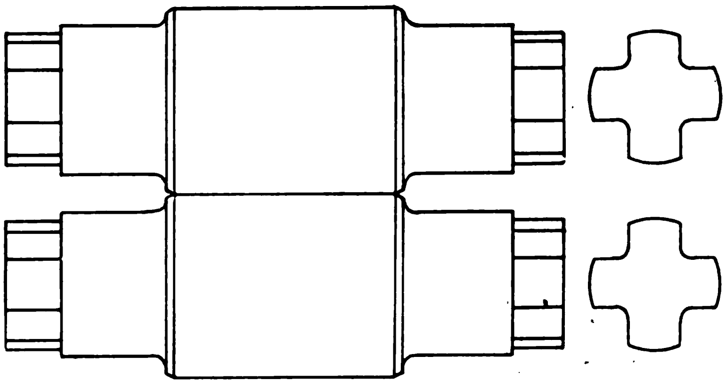

same rolls heated to working temperature

Fig. 3.

A roll can be broken with a temperature scarcely too hot to bear the hand on if it is applied quick enough, and the following conditions are believed by the writer, to be the most prolific source of trouble.

1st. The chilled surface of the roll as previously stated has an expansion approximately twice that of the gray granular interior.

2nd. Under all the present day processes of warming up, this chilled surface of the roll is the first part to be heated, thus accentuating an already precarious condition, as the chilled surface must of necessity become quite hot before the gray metal behind it is even warm. This is conclusively shown when rolls sometimes break before a half dozen bars have been rolled on them and when the heat in the roll is not sufficient to even discolor the fracture and in deep chilled rolls many are broken simply by the warming up and before even a bar has been rolled on them.

3rd. Many seemingly perfect rolls are broken during the warming up process when there is no pack in the mill. This is caused by the surface of the roll becoming heated so rapidly that the interior of the roll did not get warm enough to expand the slight amount its preponderating mass would require, to take care of the very rapid expansion of the face or chilled portion, and the roll is torn in two.

4th. It is a known fact that most of the roll breakage occurs in the fore part of the week before the rolls have reached their final working temperature, also there is more breakage in the extremely cold winter months than in the summer time, due to the lower temperature at which the warming up starts and it is the writer's opinion that no matter when the roll actually lets go the condition that finally put it out of commission was started on the warming up turn.

5th. That it is a heat condition rather than a torsion or bending stress that breaks these rolls, is self-evident when you consider that the wabbler of a roll on the leading mill, with only one-third the area of the body of the roll must transmit all of the torsional stress of all the mills on that side of the drive. Yet few wabblers are broken off in comparison to the number of rolls that are broken through the body although the body only carries its individual load.

6th. That the remedy for roll breakage is a better and slower means of warming them up until they reach the proper rolling temperature, which is assumed to be that which will produce a bright blue color on the chilled surface of the roll.

7th. While it is unquestionably true that when a roll is subjected to excessive torsional and bending stresses at the same time the rapid expansion of its face is taking place, the danger of breakage is greatly increased, the primary and most responsible cause of breakage is the too rapid heating of the face of the roll by heat applied solely from the outside through this crystalline face before the center of the roll has even had a chance to become warm.

8th. The gagging of rolls due to excessive screw or poor top neck lubrication, will result later on in both rolls breaking as the sticking of the hot bar between the rolls causes an excessive heating of this one spot on the rolls circumference, starting a fracture in the chilled face of the roll that either causes it to spawl or break later on and it can be safely figured that every time a gag occurs that it means shorter life for that pair of rolls.

9th. A broken coupling box or spindle which is not considered by the average operative as an abuse of the rolls because it is more or less beyond his control may be much worse than a gagged roll because under this condition perhaps several stands of rolls are stopped with the hot bars between them.

10th. Last but by no means least is permitting the temperature of the rolls to vary greatly up or down by irregular operation of the mill.

Acid Open Hearth Process for Manufacture of Gun Steel and Fine Steel

Detailed Description of This Manner of Work, Giving the Various Steps of Manufacture—Result of Investigations Made by Special Committee as to Difficulties Encountered.

By W. P. BARBA and HENRY M. HOWE

PART III

51. **Prevention of Transverse Cracks by Giving the Crust of the Ingot Firm Salient Ties.**—(a) The ingot may be torn transversely, not only by the resistance of the slower cooling, deeper seated layers to its longitudinal contraction, but also by any other impediment to that contraction, for instance by its being caught at its top by a fin, or by some roughness in the mold. In this case the weight of the part of the ingot below the obstruction may suffice to cause transverse cracks, especially because its effect is always aggrevated by the resistance of the slower cooling, deeper seated layers to the faster longitudinal contraction of the skin. Mechanical attachment of the upper part of the ingot to the mold is more likely to occur when the large end of the ingot is uppermost. The obstruction to longitudinal contraction is, of course, all the worse if the ingot is caught at both ends by the mold.

(b) In order to prevent this transverse cracking by excessive longitudinal stress, the ingot should be provided with saliences which, by outrunning the cooling of the non-salient parts, become in fact more or less firm ties. The four main edges of a square ingot are such saliences, which thus become longitudinal ties, and by their integral union with the metal of the faces of the square tend to prevent it from being torn transversely by the longitudinal stress.

52. **Octagonal and Square Molds.**—(a) The chief advantage of an octagon is that it has twice as many of these supporting edges to act as longitudinal ties, and prevent the faces between from being torn across by any resistance to the longitudinal contraction of the ingot.

(b) It might at first be thought that, if increasing the number of faces from four in a square to eight in an octagon is an advantage, we should get a further advantage by still further increasing them to twelve or even more. In some works ingots with as many as twelve edges are made. But if we push this too far we fail to accomplish what we seek. If the number of edges were infinite, the ingot would be a cylinder. It would in the first place have the most unaccommodating shape possible, and in the second place would have no ties for preventing the cracking of the faces. The more edges there are, the less can each edge project beyond the faces between which it lies, without running the risk of cracking in cooling, and of folding in forging, and the less therefore can it outrun the cooling of the faces and the less support can it give them.

(c) The purpose of making the faces of the octagon concave is to give its eight edges greater salience, so as to increase the degree to which they outrun the cooling of the faces between them, and thus to increase the support which they offer them.

(d) The square has the further disadvantage when compared with the octagon that its corners in cooling tend to outrun the intermediate faces so greatly that a sort of St. Andrew's cross, or plane of weakness running diagonally from corner to corner of the square, forms readily. It is the junction of columnar crystals out from the adjoining faces.

This tendency should be lessened, first by making the mold much thinner at the corners than at the faces of the square, and second by rounding the corners. Yet this rounding should leave them as sharp as is compatible with their not crusting during pouring, and with their not forming these diagonal planes of weakness, because to dull them brings the periphery toward the cylindrical form, and thus lessens its power of accommodating itself to the resistance of the slower cooling interior. In general, the radius of the faces is about half the diameter of the ingot.

TABLE 1.—DIMENSIONS OF INGOT MOLDS

Nominal Size.	18 In. Sq.	26 In. Oct.	35 In. Oct.	40 In. Oct.	45 In. Oct.
Radii, in in.:					
of edges ..		1.50	1.50	1.50	1.25
of fluting .		14.875	20.00	20.00	28.00
Taper, inches, of diameter per foot of height	0.3985	0.4220	0.4232	0.4305	0.4148
Height, in...	60.25	87.312	76.062	78.375	76.75
Ratio height to nominal diameter ..	3.35:1	3.36:1	2.17:1	1.96:1	1.71:1
Ratio, thickness of ingot to thickness of wall at top	5.38:1	4.29:1	4.21:1	4.46:1	4.57:1
At bottom.	2.30:1	2.63:1	3.17:1	3.18:1	3.81:1

Square ingots may well have concave sides between the corners of the square, if they are to be bloomed, so that they may ride more easily, and be the more easily guided, on the feeding table of the blooming mill; whereas they are frequently made convex when the ingot is to be forged. In an octagonal ingot, the faces should have the shortest radius, and the edges the greatest salience, which will not lead to the formation of folds in forging.

(e) An additional reason for not making the vertical edges of either the square or the octagonal mold too strongly salient, is that the salience, if too strong, would outrun the rest of the ingot in heating for forging so greatly as to be in danger of being burned. There are other limiting considerations which could be discussed, were it not for burdening this paper with too much detail.

53. **Examples of Molds.**—Table 1 gives the dimensions of ingot molds of five different sizes from very good practice. The molds would probably be improved by thinning their walls at the top and thickening them at the base. The tapering of the mold walls has been carried out successfully ever since 1897 in making fine steels.

One steel maker advises that, for ingots about 24 in. in diameter, the ratio of the cross-section of the mold to that of the ingot should be two to one at the bottom and a little more than one to two at the top, though this may make the mold too fragile at the top for rough work. On the other hand for ingots more than 24 in. in diameter, the two to one ratio would give the bottom of the mold a clumsiness that would hardly be compensated for by the extra heat which it would absorb from the ingot bottom. Hence this ratio should decrease as the diameter of the ingot increases beyond 24 inches.

54. **Hot Top and Discard.**—(a) The ratio of the steel in the hot top to that in the ingot proper should, in general, be from 15 to 25 per cent, according to the specifications as to top discard. For instance, for gun steels the Government requires 30 per cent. top discard. It is convenient and wise to let 25 of this 30 per cent be made up by the steel contained in a sand-lined sink head, and the remaining 5 per cent by the few inches of the top of the ingot proper which could not be used for gun steel in any event, because they form the joint between the ingot and the skin head.

(b) The purpose of the discard is to remove any mechanically unsound parts, and any that are unduly enriched in phosphorus and sulfur by segregation. With the use of a hot top, and with well-made steel carefully poured, there is much less than 30 per cent of the ingot that is subject to mechanical unsoundness. Moreover with well-made, thoroughly deoxidized steels very free from phosphorus and sulphur, such as can be made in the electric furnace, the content of phosphorus and of sulphur cannot become harmfully great even at the local enrichment at the ingot top. Hence it is expected that this 30 per cent top discard will be reduced to 20 per cent, or even less in special cases. This would be wholly justified.

(c) The use of sink heads of sand in top pouring is open to the objection that the stream of very hot steel, running down in the neighborhood of the sand, is apt to heat it so suddenly and so highly that it disintegrates, so that enough of it runs down into the mold to add appreciably to the inclusions.

(d) The use of carbonaceous material in the sink head implies a certain danger that the carbon may be taken up by the upper layers of steel, and may be carried down to a very considerable depth, partly by diffusion and partly by convection. Sulphur prints of ingots have shown clearly, what was indeed evident on careful consideration, that there is a very great degree of sagging down or sinking down along the axis of the ingot.

55. **Top and Bottom Pouring.** — Bottom pouring has the advantages:

(a) That in it the upper surface of the molten metal is visible throughout the operation, for the guidance of the pourer, whereas during the early part of top pouring from a bottom-poured ladle the ladle itself cuts off our view of the surface of the ingot. This disadvantage of top pouring may sometimes be avoided by pouring from a lip, or through a head box.

(b) That the surface is not disturbed, as in top pouring, by the impact of a falling stream of metal, and hence that its indications are more decisive, more easily interpreted.

Both these advantages are of less weight for very wide ingots than for those of intermediate size, because the surface of the former becomes fully visible earlier, and is less disturbed by a descending top poured stream than that of the latter.

(c) That it permits group pouring, leading to great uniformity of conditions among the ingots of a given lot.

(d) That during all but the latter part of the pouring, the rapid uprush of the stream along the axis of the mass tends to lessen the quantity of heat which it transfers to the lower part of the ingot, and to increase correspondingly that which it gives to the ingot top, thus lessening the tendency to pipe. This effect of bottom pouring is favored by the shape which the inner surface of the walls of the ingot assumes, that of an inverted cone. This merit of bottom pouring increases with the velocity of the uprising stream, and hence increases with the size of the ingot, and decreases as the pouring progresses.

(e) That it avoids cutting the bottom of the mold by the impact of the falling stream of metal, as occurs in top pouring of long ingots.

On the other hand bottom pouring is at a disadvantage:

(f) In needing more complicated molds, more expensive to place.

(g) In scrapping some of the metal in the form of runners, etc.

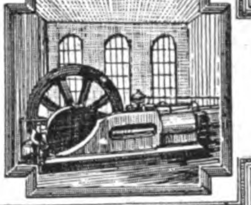
(h) In its liability to befoul the steel with matter cut or fluxed from the runner bricks.

(i) In increasing the danger of "run-outs" by its keeping the metal in the runners molten.

(j) In giving up to the bottom of the ingot an undue proportion of the heat of the last of the fresh hot steel added, thus increasing the tendency to pipe. This is because, during the last of the pouring, the rise of the incoming steel along the axis of the ingot is necessarily slow, both because now the level of the steel in the mold can be but little below that in the runner, and because the steel must now be added cautiously and hence slowly in order that the ingot may be given the predetermined height accurately. In top pouring, on the other hand, the last of the hot steel is added directly and slowly to the top of the ingot to which most of its heat is transferred, very little reaching the lower part of the mass.

This advantage of top pouring probably outweighs the corresponding advantage (d) of bottom pouring, both because the upward concentration of heat by (d) does not apply to the uppermost part of the ingot, the part which has the greatest effect on the piping tendency.

STEAM POWER DEPARTMENT



The Field of the Large Boiler

Some Interesting Data on the Large Boilers Installed at the River Rouge Plant of the Ford Motor Company—Charts Showing the Boiler Efficiency.

By J. B. CRANE

We can all remember when the first large turbine units were installed how the majority of the engineers said the field would be limited, that it was much better to have a large number of small units, so that if anything happened to one unit, only a small percentage of the total power apparatus would be shut down.

The history of the first large turbines tended to strengthen the stand of these engineers, as considerable trouble developed with the turbines on account of the difficulty in securing materials that would stand up under the stresses imposed and which were not thoroughly understood at that time.

However, today no one hesitates about installing large turbines, generators and transformers, if the load conditions warrant it.

In other words, the large turbine with its multitude of blading, piping, valves, generator and exciter, condenser and auxiliaries, wiring and switches, has proved its reliability.

If two to four boilers are considered sufficient to supply steam for a 5,000 or 10,000 kw. turbine, it should not require more than this number of boilers for a 20,000 or 40,000 kw. turbine, and when it is realized how much less apparatus there is to get out of order with a boiler and its auxiliaries than with a turbine and its accompanying apparatus, there must be something wrong with boiler designers if they fail to deliver the goods.

The first large boilers (2365 hp.) were installed at the Delray plant of the Detroit Edison Company, and their operation was so successful that when the Connors Creek plant was built by the same company in 1914, boilers of the same capacity were installed with the intention that two boilers would supply steam for one 25,000-kw. turbine, when the boilers were operating at 170 per cent of rating. No spare units were installed, and experience has shown that two turbines can be safely and economically operated with three boilers at 225 per cent rating.

Boilers of 2500 hp. capacity were installed by the Ford Motor Company at their Highland Park plant, but this rating included pre-heaters, which it was subsequently necessary to abandon on account of corrosion troubles.

At the River Rouge plant of the Ford Motor Company Ladd 2647-hp. boilers were installed in 1920, and these have now been in operation long enough so that some of the operating results are of interest.

Boiler No. 1 was put in service November 12, 1920, and operated continuously under loads varying from rating to 300 per cent for 140 days, when it was first shut down for purpose of inspection. After six days the boiler was again put on the line and ran for 133 days under the same loads as above. The second shut-down was for the purpose of inspection, cleaning accumulated ash from boiler setting walls and replacement of a leaky superheater unit.

It was again started September 29, was still running on March 1, a period of 183 days, and the initial efficiency was being maintained.

The other three boilers show similarly good operating records; there have been two boiler tubes lost on the four boilers in 15 months, and these were removed during periods of inspection, due to the presence of small blisters which it was feared might later cause trouble.

A very careful examination of the setting was made on No. 4 boiler after a year's operation, and it was the opinion of the engineers making the inspection that there would be no serious trouble with the brickwork for several years.

Apparatus is being assembled to run complete tests on these boilers, but in the meantime it may be interesting to observe the following figures which are obtained in daily operating practice, as shown by the weights of coal taken daily, and output, by integrating the curves of the steam flow charts:

Load	Flue Gas Temp. F.	CO_2%	Estimated Efficiency	Draft Loss: Inches of Water
100	455	15	82.8%	0.25
200	490	15.6	82.7	0.50
300	560	15.0	80.2	1.0
400	670	14.8	74.0	2.0

These boilers have no economizers and the above efficiencies show per cent of heat absorbed by boiler and superheater on basis of gross heating value of coal.

Tests for moisture in steam from boiler showed 1.2 per cent at 300 per cent rating and less than 1 per cent at 200 per cent rating.

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Another interesting feature of the installation at the River Rouge plant is that these are the first boilers to use blast furnace gas and powdered coal in combination.

Enough blast furnace gas is furnished to carry 1900 to 2000 hp. on each boiler, and powdered coal is used to furnish deficiencies, and loads in excess of that that can be carried by blast furnace gas. The powdered coal equipment and blast furnace gas burners were furnished by the Combustion Engineering Company, and the operation is highly satisfactory. There are no driers and while the coal ordinarily contains 5 to 6 per cent moisture, coal containing 12 per cent moisture has been burned.

The superheaters are Elesco, made by the Superheater Company, and it is interesting to know that the total steam temperature as delivered from the superheater varies less than 10 per cent with a variation of load from 150 to 400 per cent of rating.

The accompanying charts show the type of load on these boilers and one of the big advantages is the speed with which loads can be increased and decreased almost instantaneously.

The cost per horsepower for boilers alone for two 3,000 against four 1500 or six 1000 hp. boilers will be very nearly the same, but the largest boilers will require less floor space, less excavation, less foundations, less steel work, less building, less roof, less valves, less piping, less brick in the setting; and the final cost installed will be less than for the greater number of smaller boilers; and as there will be less furnace wall about the boilers the loss by radiation will be less; and consequently, all other things being equal, the efficiency will be higher, there will be less labor required to operate the boilers, and these operators will have less apparatus to watch and can give it very much better attention, so that both the thermal and economic efficiency will be higher.

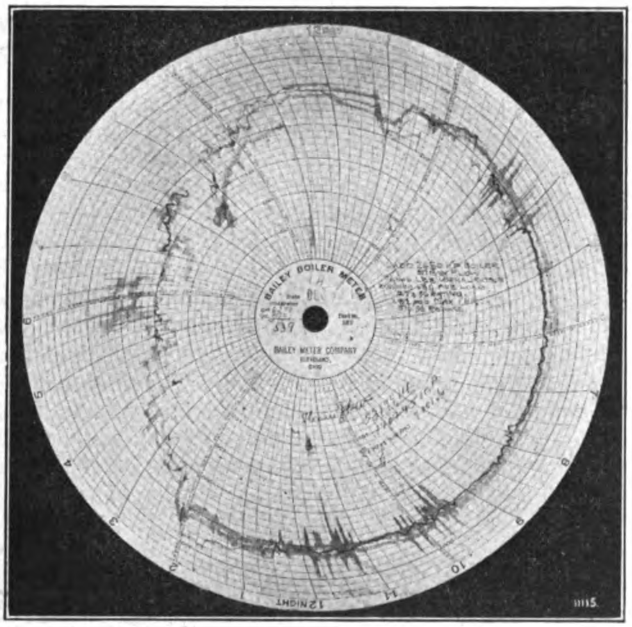

Fig. 1—Chart showing operation of boilers in Ford plant.

Boilers up to 9000 hp. normal rating can be built with materials now available, and the stresses will be no greater than that prevailing on this installation.

There is considerably more flexibility than exists on the turbine end of the plant, where a turbo-generator will carry its rated capacity and no more.

The flexibility, when proper methods of fuel burning are used, is so great that it is safe for engineers to figure on two boilers to carry their entire load at 190 to 200 per cent of rating, and in emergencies one boiler will carry the entire load at 380 to 400 per cent of rating.

Consideration must also be given to the character of the load, for it would of course be manifestly unwise to install two boilers to operate a load that only lasts for a short period of each year, when the load for the remainder of the year is very much less; and under these conditions the proper number of boilers should be installed to take care of the minimum as well as the maximum conditions.

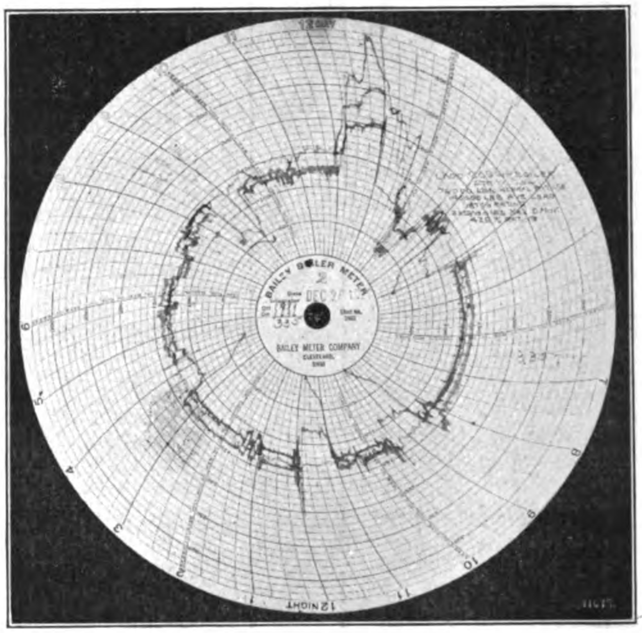

Fig. 2—Chart showing operation of boilers in Ford plant.

LETTER TO THE EDITOR

Dear Sir:

We have read over our article entitle entitled "Air Required for Combustion of Gases" which appeared in BLAST FURNACE AND STEEL PLANT March, 1922, pages 174-175.

We find a different constant in the formula gives values, especially in the lower part of the curve, much nearer the actual data.

The exact formula should be:

Cubic feet of air theoretically needed per cubic foot of gas $= \frac{9.67\ \text{Btu.}}{1000} - .25$

and the approximate formula should be:

Cubic feet of air theoretically needed per cubic foot of gas $= \frac{\text{Btu.}}{1000} - .25$

We regret that this error was not discovered before submitting the article and trust that its rectification will cause no inconvenience.

Very truly yours,

A. F. SPIEHLER.

Reduction of Fuel Wastes in the Steel Industry

By **F. G. CUTLER**, Ensley, Ala.

The paper sets forth the economy of utilizing blast furnace gas, at one time considered to be of little material value, in reducing the wastes of the steel industry. It is shown how the quantity of gas to be expected in the production of one ton of pig iron may be computed, and the uses to which this gas may be put are analyzed quantitatively. A heat balance, based on the production of one ton of pig iron, is presented, showing the sources of heat and the requirements for blast furnace and steel mill operation. It shows that the total heat from the by-products of a ton of pig iron is more than sufficient to finish a ton of steel. The heating requirements are not met by the tar and by-product gas, although the average power requirements are more than met by the blast furnace gas and coke breeze. It therefore becomes desirable to reduce the heating requirements for the production of steel by using more efficient heating furnaces, and to conserve all possible heat by charging hot steel into the soaking pit and reheating furnaces, in order to reduce the quantity of fuel required for supplementary heating.

IN this period of readjustment there is every reason for the reduction or, if possible, the elimination of waste, and the managers and engineers of the steel and iron industry have been alive to the advantages resulting from the conservation of fuel. There are, however, in this and in all allied by-product industry, a number of opportunities for reduction in the consumption of fuel, some of which have been discussed many times and others only briefly touched upon.

In order to show the relative proportion of the energy in the shape of heat or power required for the manufacture of steel that is utilized from the fuel by-products of the manufacturing process, the following figures have been prepared showing the quantity of heat derived from the by-products of the manufacture of pig iron.

In the production of one ton of pig iron, from under 1800 to over 3000 lb. of coke are used, this variation being due to difference in metallic content of the charge, condition of the furnace lining, quality of coke, etc. The heat energy of this coke is utilized in the reduction of the ore to pig iron and changing the impurities to a slag; a part is lost in radiation, and approximately half is delivered at the top of the furnace in the shape of gas for use under boilers for the production of steam, or in gas engines for the production of power. The gas has also been used in soaking pits, in by-product oven heating, ladle drying, etc., and other uses have been proposed, but by far the greatest quantity has been used under boilers.

It has been only within the last few years that blast-furnace gas has been considered to have any material value. The value generally placed upon gas, and appearing as a credit to blast-furnace cost, has been based upon the cost of the coal replaced by the gas, with an allowance for the cost of firing coal; and even with comparatively inefficient boilers, and in many cases the lack of efficient supervision, the cost of steam in these boiler plants has been generally low. The coke consumption of the blast furnaces which largely determines the volume and Btu. value of gas was variable, and the steam consumption both of the blast furnaces and of other departments supplied from the furnace plant varied widely. The credit was largely an estimate, and at times when the gas supply exceeded the demand, steam or blast-furnace gas was wasted. The blast-furnace superintendent was generally interested mainly in obtaining as high stove heats as could be carried, regardless of how much gas was wasted at the stoves through leaving the gas on after they had become heated, or by forcing gas to the stoves above their efficient combustion capacity. Gas was similarly wasted at boilers, due to too small combustion chambers, inefficient gas burners, lack of proper baffling, or lack of proper attention paid to combustion. With nominal coal costs this waste might be excused but with the realization that coal deposits have a limit and with the increasing value of coal and its by-products, any waste of fuel should be stopped provided the cost of eliminating the waste is not excessive.

In the past there has been no recognized method of determining whether or not a blast-furnace plant has been guilty of wasteful practice, or if guilty, what the extent of this waste might be, and it is the intention of this paper to propose a standard method of comparison of total combustion efficiency, both with the idea of determining, for any particular plant, the relative efficiency, from day to day or month to month, as well as for the comparison of one blast-furnace plant with another, for the information of the management and the engineers in determining the necessity for improvement in equipment or personnel. Reference is made particularly to the latter, for the reason that after twenty years' experience around blast-furnace plants the author has found that there is generally a greater gain in efficiency possible per dollar of expenditure by efficient attention to operation of existing equipment, than by making changes in equipment without proper supervision.

Heat Available From the Blast Furnace.

In proposing this standard comparison reference is

For presentation at the Spring Meeting, Atlanta, Ga., May 8 to 11, 1922, of The American Society of Mechanical Engineers, 29 West 39th Street, New York.

made to Fig. 1 which is taken from Mr. Brassert's paper on Modern Blast Furnace Methods, published in the year book of the American Iron and Steel Institute in 1914. This chart shows the effect of variation in coke rate upon the heat value of blast-furnace gas at 62 deg. Fahr. As blast-furnace gas leaves the top of the furnace it usually has a temperature of from under 300 to over 600 deg. Fahr., generally averaging about 400 deg. Fahr. At this latter temperature, the sensible heat of the gas is equivalent to about 8 Btu per cubic foot of gas at 62 deg. The Btu per cubic foot of blast-furnace gas according to Brassert is $62.5 + 0.016\mathbf{R}$, where $\mathbf{R}$ = lb. of dry coke per ton of pig iron; and including sensible heat of the gas at 400 deg. Fahr. would be equal to $70.5 + 0.016\mathbf{R}$. The cubic feet of gas per ton of pig iron (as shown by Brassert) is equal to $71.4\mathbf{R}$, so that in the top gas from a furnace at 400 deg Fahr. the Btu per ton of iron is $1.142\mathbf{R}^2 + 5033.7\mathbf{R}$. Brassert also gives the cubic feet of air per pound of coke equal to $51.4\mathbf{R}$, so that both gas production and the blast requirement bear a direct ratio to the coke consumption of the furnace per ton of iron. The figures given in Mr. Brassert's paper, so far as the author has been able to discover, are applicable to all blast furnaces using coke as fuel.

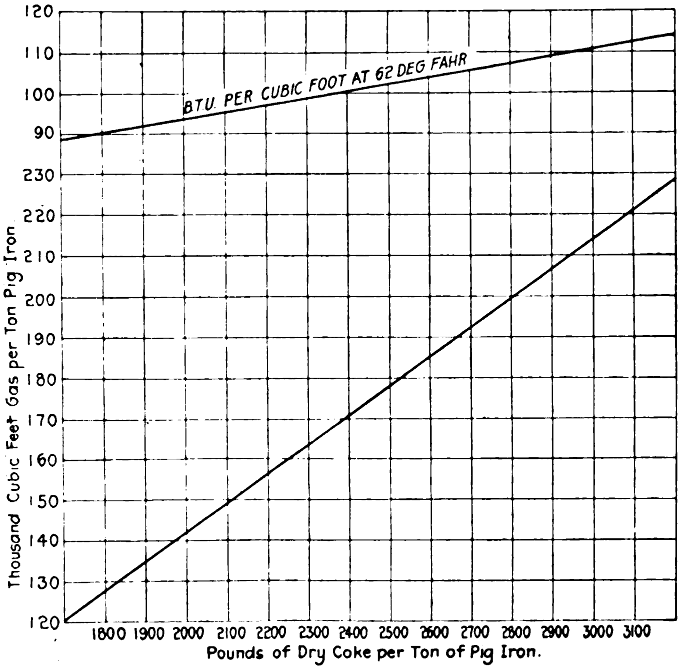

Fig. 1—Effect of coke rate on production of blast-furnace gas.

Heat Required For the Stoves.

The blast is heated in stoves under pressure, and the heat required per cubic foot of blast is proportional to the rise in blast temperature in the stove, and inversely proportional to the efficiency of the stove, which is usually considered to average 60 per cent. After the necessary gas is used to heat the blast, the remainder can be measured in the shape of power. Any increase in stove or boiler efficiency or reduction in leakage of gas, etc., is reflected in increased surplus power, and as we are largely interested in the surplus power, after the blast furnace requirements are satisfied, any error in the assumptions relative to the efficiency of the stoves is of minor importance, particularly as the stoves use the smaller fraction of the total. The blast supplied from the blowing engines is heated by compression to about 150 deg. Fahr., varying somewhat with blast pressure, etc., and is usually heated in the stoves to from 1150 to 1350 deg. Fahr. In the following calculations it has been assumed that 0.02 Btu are required per cubic foot of blast per deg. Fahr., that the blast is heated in the stoves to 1250 deg. Fahr., that the average over all stove efficiency (i. e., ratio of heat given to the blast to the heat in the gas) is 60 per cent and that 55 cubic feet of blast are heated per pound of coke charged.

The heat required in the gas for heating the blast for one ton of pig iron to a temperature of 1250 deg. Fahr. can therefore be expressed by the following formula where $\mathbf{H}$ = Btu per lb. of coke burned in the blast furnace.

$$\mathbf{H} = \frac{(1250 - 150) \times 0.02 \times 55\mathbf{R}}{0.60} = 2020\mathbf{R}$$

The heat in gas per ton product after the blast is heated is, therefore, $1.142\mathbf{R}^2 + 3013.7\mathbf{R}$. For other top temperatures and blast temperatures the constants will change slightly.

Heat Required For Gas-Fired Boilers.

In order not to enter into the discussion of the relative merits of steam vs. gas engine, surplus uncooled gas, after the stoves are heated, will be assumed to be used under boilers. In one boiler horsepower-hour there are 33,305 Btu, and assuming that the "standard" efficiency of blast-furnace-gas-fired boilers is 66.6 per cent, in one boiler horsepower-hour

$$\frac{33{,}305}{0.666} = 50{,}000 \text{ Btu}$$ would be required in the gas, so that the boiler hp-hr. per ton would be

$$\frac{\text{Surplus Btu per ton iron}}{50{,}000 \text{ Btu}}.$$ As the blast-furnace product is usually expressed in tons per day the average boiler horsepower per hour generated from blast-furnace gas under the above conditions can be expressed by the formula:

$$\text{Average boiler horsepower per hour per ton of pig iron per day} = \frac{1.142\mathbf{R}^2 + 3013.7\mathbf{R}}{50{,}000 \times 24}$$

In assuming the standard efficiency of 66.6 per cent for boilers and 60 per cent for stoves, it should not be understood that these are the maximum efficiencies that can be attained, but rather that they are taken as a standard for comparison and represent average practice that can be maintained in a fairly modern plant correctly designed, and operated by reasonably intelligent men.

Using the above, Fig. 2 has been prepared. This chart also shows the per cent of top gas required for heating the blast to an average of 1250 deg. Fahr. with the stoves of 60 per cent total efficiency. This chart can be used by the blast furnace superintendent or engineer to determine the horsepower that should have been generated from gas for any period. From the actual results as shown by a meter on the boiler feed line, after deducting an allowance for steam generated by coal firing (usually small) or for gas used by gas engines, it will be possible to determine whether the total efficiency, including stoves and boilers, is above or below the standard.

The following table shows the boiler horsepower-hours per ton of pig iron for several coke rates as calculated from the above formula.

Pound of Coke per Ton.	Boiler-Horsepower-Hours per Ton Product.	Boiler-Horsepower-Hours per Ton per Day.
2000	211	8.8
2200	242	10.1
2400	276	11.5
2600	310	12.9
2800	348	14.5
3000	386	16.1

To furnish the blast to the furnace with either high-pressure condensing, turbo-blowers or reciprocating steam engines requires about 70 boiler hp-hr. per ton of coke burned in the blast furnaces, and to operate the various furnace auxiliaries, such as pumps, air compressors, steam bells, mud guns, hoists, etc., requires from 15 to 25 boiler hp. per ton of product, so that after the furnace requirements have been met, there is available for the generation of power from 100 to 250 boiler hp-hr. per ton of pig iron, depending on the coke burned in the furnace.

At 2 kw. per boiler hp-hr., this means that from 200 to 500 kw-hr. per ton of pig iron is possible with steam equipment from the surplus gas from the blast furnaces.

Heat Required for Manufacture of Steel from Pig Iron.

The manufacture of steel from pig iron in the open hearth requires heat for melting scrap and fluxing the impurities, and power for the various operations incident to this process. The quantities of heat and power vary materially with different plants on account of difference in equipment, practice, etc., but for the purpose of this paper it will be assumed that a ton of ingots requires one ton of pig iron plus enough scrap to offset the losses and that this work requires from 5,000,000 to 9,000,000 Btu and an expenditure of from 20 to 30 kw-hr. per ton. This ton of ingots will make about 0.85 tons of blooms, and the heating in soaking pits will require from 1,500,000 to 3,500,000 Btu per ton of steel depending upon the temperature of the steel arriving at the pits, rate of operation, etc., and the rolling of the ingots into blooms will require from 40 to 60 kw-hr. per ton. From the blooming or slabbing mill the material, usually reheated at an expenditure of from 2,500,000 to 6,000,000 Btu per ton, is furnished to finishing mills, the power required, depending on the reduction of section, temperature of rolling, etc., varying from 35 to over 300 kw-hr. per ton.

Utilization of the Industrial Wastes.

Waste heat from the open hearth and heating furnaces and kilns is utilized for the production of steam, and otherwise waste steam is utilized in low or mixed pressure turbines for the production of power, but as these subjects have been discussed many times, and are not peculiar to the steel industry, they will not be discussed except to say that while these economies are many times worth while in existing plants, very few new installations as designed include waste-heat boilers with furnaces, or low-pressure turbines as integral parts of new power plants.

Surplus by-product gas, after the ovens are heated, is sold for use as domestic fuel, etc., replacing natural gas, water gas, etc., and is used in the steel plant for melting steel in the open hearth, and for various heating operations in the steel industry. In former years this material was considered as having only nominal value and only rarely was any attempt made to utilize it efficiently.

With the advance in fuel prices, shortage of natural gas, etc., and also largely due to special heating requirements connected with the manufacture of artillery and ammunition during the war, a number of combustion systems were developed that by more or less accurately regulating the proportion of air to gas have greatly increased the combustion efficiency of heating furnaces, and the control of combustion has been found of great importance in the maintenance of economy.

Dust coke breeze, from the coke plant (i. e., the material through a ⅜-in. screen), is used to cover molten pig iron in transit from the furnaces and in making bottoms of soaking pits and heating furnaces.

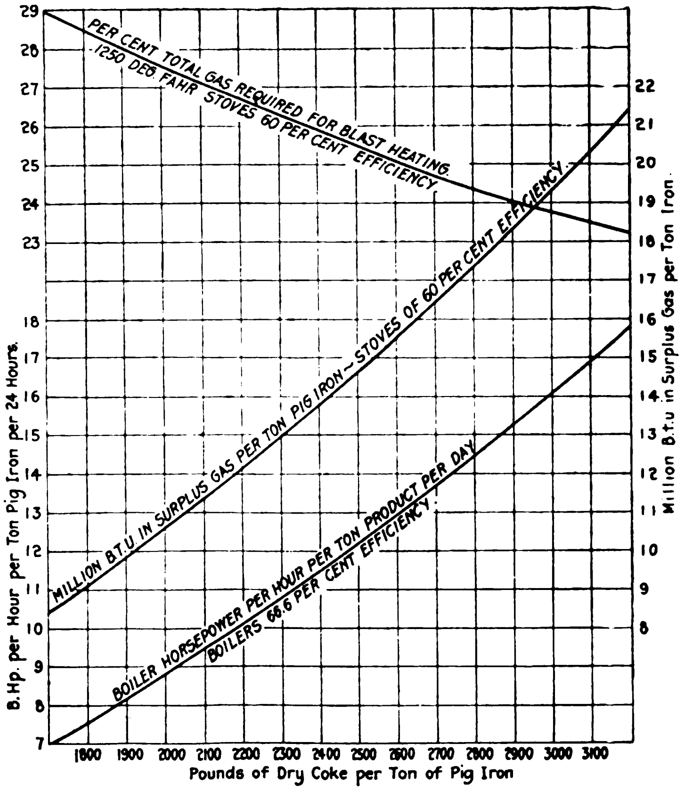

Fig. 2—Effect of coke rate on production of power from surplus blast-furnace gas.

A great deal of this material which was thrown away or more or less inefficiently burned on hand-fired grates, or by mixing with slack, on mechanical stokers, is now more efficiently burned by itself, on traveling-grate forced-blast stokers.

Tar, either before or after the creosote oils have been removed, has been found to be a very good fuel for open-hearth furnaces, either by itself or in conjunction with by-product gas, and has been used for steam production either as an auxiliary fuel on blast-furnace boilers or by itself, and its use has been proposed to heat by-product ovens, thus releasing additional gas otherwise required for heating the ovens.

Heat Balance.

Table 1 gives an example of the approximate heat balance of one ton of pig iron as used in the steel plant, using average figures, and based on an average coke consumption in the blast furnace of 2500 lb. of coke per ton of product.

TABLE 1.

Heat balance for manufacture of one ton of pig iron.

From the coke plant delivering one ton of coke there result the following fuel by-products for consumption in the steel plant after the heat and power requirements of the by-product plant have been met:

	Btu.	Btu.
12 gal. tar at 162,500 Btu per gal., Btu	1,950,000	
30 lb. of coke breeze at 12,000 Btu per lb., Btu	360,000	
10,000 cu. ft. gas at 500 Btu per cu. ft. (net value), Btu	5,000,000	
Total per net ton coke		7,310,000
Heat available per ton pig iron		
In tar from by-product plant	2,435,000	
In coke breeze from by-product plant	450,000	
In surplus gas	6,250,000	
Surplus from by-product plant		9,135,000
In blast furnace gas		19,635,000
Required for blast heating	5,000,000	
Required for blowing equipment	4,400,000	
Required for blast-furnace operation	1,000,000	
Required for total blast furnace		10,400,000
Surplus from blast-furnace plant		9,235,000
Total heat energy from by-products		18,370,000
Heat required for steel plant		
Open hearth (pig iron to ingots)		
Melting (approx)	7,000,000	
Power, 25 kw. at 25,000 Btu per kw-hr	625,000	
Total heat consumption		7,625,000
Roughing Mill		
Heating (approx.)	2,000,000	
Power, 50 kw-hr	1,250,000	
Total		3,250,000
Finishing Mill		
Heating (approx.)	4,000,000	
Power, 100 kw-hr	2,500,000	
Total for finishing		6,500,000
Total heating requirements	13,000,000	
Total power requirements	4,375,000	
Total		17,375,000

Necessity of Heat Conservation.

From Table 1 it will be seen that the total heat from the by-products of a ton of pig iron is more than sufficient to finish the average ton of steel, but upon inspection of the table it will be found that the heating requirements have not been met from tar and by-product gas, while the average power requirements are more than met from blast-furnace gas and coke breeze.

It therefore becomes very desirable to reduce the heating requirements for production of steel by using more efficient heating furnaces, and to conserve all possible heat by charging hot steel into the soaking pit and reheating furnaces, in order to reduce the quantity of fuel required for supplementary heating.

The production of gas at the by-product plant is practically uniform, while the consumption at the steel plant is variable and as a result the gas pressure at the steel plant (usually some distance away from the by-product plant) is variable. As gas holders of sufficient capacity to absorb the fluctuations have not been found advisable it becomes necessary to schedule the use of gas by consuming departments in order partially to equalize the consumption. In many cases it is advisable to use by-product gas under boilers (although it is more valuable for other purposes) in order to prevent or reduce its waste, as it is easier to change from gas to coal on boilers than to fire up producers.

One of the most important problems of the steel plant manager and engineer is so to regulate the production and consumption of the various fuels occurring as a by-product of steel plant manufacture that the consumption of raw coal in producers or under boilers that would otherwise be sent to the by-product plant is a minimum, for the reason that the by-products from the coal, coked in the by-product plant, usually exceed any possible return as fuel.

PUBLICATIONS ON THE UTILIZATION OF COAL.

A limited supply of the following publications of the Bureau of Mines has been printed and is available for free distribution until the edition is exhausted. Requests for all publications can not be granted, and to insure equitable distribution applicants are requested to limit their selection to publications that may be of especial interest to them. Requests for publications should be addressed to the Director, Bureau of Mines.

The Bureau of Mines issues a list showing all its publications available for free distribution as well as those obtainable only from the Superintendent of Documents, Government Printing Office, on payment of the price of printing. Interested persons should apply to the Director, Bureau of Mines, for a copy of the latest list.

Publications Available For Free Distribution.

Bulletin 40. The smokeless combustion of coal in boiler furnaces, with a chapter on central heating plants, by D. T. Randall and H. W. Weeks. 1912. 188 pp., 40 figs.

Bulletin 58. Fuel briquetting investigations, July, 1904, to July, 1912, by C. A. Wright. 1913. 277 pp., 21 pls., 3 figs.

Bulletin 116. Methods of sampling delivered coal, and specifications for the purchase of coal for the Government, by G. S. Pope. 1916. 64 pp., 5 pls., 2 figs.

Technical Paper 9. The status of the gas producer and of the Internal-combustion engine in the utilization of fuels, by R. H. Fernald. 1912. 42 pp., 6 figs.

Technical Paper 50. Metallurgical coke, by A. W. Belden. 1913. 48 pp., 1 pl., 23 figs.

Technical Paper 80. Hand firing soft coal under power-plant boilers, by Henry Kreisinger. 1915. 83 pp., 32 figs.

Technical Paper 89. Coal-tar products and the possibility of increasing their manufacture in the United States, by H. C. Porter, with a chapter on coal-tar products used in explosives, by C. G. Storm. 1915. 21 pp.

Technical Paper 123. Notes on the uses of low-grade fuel in Europe, by R. H. Fernald. 1915. 37 pp., 4 pls., 4 figs.

Technical Paper 137. Combustion in the fuel bed of hand-fired furnaces, by Henry Kreisinger, F. K. Ovitz, and C. E. Augustine. 1916. 76 pp., 2 pls., 21 figs.

Technical Paper 139. Low-rate combustion in fuel beds of hand-fired furnaces, by Henry Kreisinger, C. E. Augustine, and S. H. Katz. 1918. 52 pp., 9 figs.

Technical Paper 180. Firing bituminous coals in large house-heating boilers, by S. B. Flagg. 1917. 22 pp., 1 pl., 16 figs.

NEWS OF THE PLANTS

The Petroleum Iron Works, Sharon, Pa., is concluding negotiations for the purchase of the plant of the Beaumont Shipbuilding & Dry Dock Co., Beaumont, Tex., for a consideration said to be about $300,000. The plant upon acquisition will be used as a southern branch works for the manufacture of oil tanks, tank cars, etc. The site approximates about 71 acres, and early proposed expansion will include the erection of a number of new buildings to be equipped as a complete steel fabricating works. The property is being secured in the name of the Petroleum Land Company, a subsidiary organization.

The Gerson Rolling Mills Corporation, Birmingham, Ala., is perfecting plans for the early erection of an addition to its plant for increased production. The primary installation will consist of a new mill for the manufacture of steel bar stock, and it is proposed to double the output in this and other departments. The expansion is estimated to cost about $100,000.

The Worcester Pressed Steel Company, Worcester, Mass., is arranging for the early installation of new precision cold rolling mills for flat strip steel production, and it is planned to provide for extensive increase in this department of the works. The mills will be equipped with steel rolls, 6 inches in diameter and of 4-inch face, permitting a maximum width of stock rolled of 3⅝ inches. The new mills will be motor-driven.

The General Iron Works Company, Denver, Colo., has acquired a large tract of land at Englewood, Colo., totaling about 18 acres, and plans to use the site for the erection of a new plant. Plans will be prepared at an early date, covering the construction of a number of one-story buildings, estimated to cost about $750,000, including machinery. The different structures will be devoted to general iron working, steel fabrication, steel casting production, etc. Erection will be commenced early in the summer, and it is proposed to have the initial buildings ready for service late in the fall. The various departments will be used by the different subsidiaries of the company, including the Colorado Iron Works, the Denver Engineering Works, the Queen City Foundry Company and the Stearns-Rodger Manufacturing Company.

The Dominion Alloy Steel Company, recently organized with a capital of $15,000,000, has plans under way for the erection of a new plant on site selected at Sarnia, Ont., for the manufacture of high carbon steel, steel alloys and kindred products. The plant will consist of a number of buildings and will be equipped for an initial output of about 50,000 tons of material per year. The company has arranged for a bond issue of $3,500,000, to provide for erection and equipment. George A. Simpson, Hamilton, Ont., is vice-president of the company and will be in active charge of the project. The directors of the company and officials in charge include Harry R. Jones, head of the United Alloy Steel Corporation, Canton, Ohio, and Harold Wills, head of the Wills-Sainte Clare Automobile Company, Marysville, Mich.

The Sloss-Sheffield Steel Company, Montgomery, Ala., has tentative plans under consideration for the construction of an addition to its plant for considerable increase in capacity. The work will include a new blast furnace with daily output approximating 250 tons.

The Riverdale Rolling Mill Company, East One Hundred and Thirty-seventh Street and the tracks of the Illinois Central Railroad, Chicago, Ill., is planning for the rebuilding of the portion of its plant destroyed by fire, March 25, comprising a large two-story structure. The loss is estimated at approximately $50,000, including equipment.

The Cadillac Malleable Iron Company, Cadillac, Mich., has work under way on an addition to its plant for increased output, comprising a one-story building, 120 x 200 feet, to be devoted to general iron working. It is planned to construct other additions at a later date.

The Andrews Steel Company, Newport, Ky., has secured options on property forming a portion of the former works of the Hecla Cement Company, Bay City, Mich., totaling about 150 acres of land and a number of buildings, as a site for the establishment of a new steel mill. It is said that the purchase will be made at an early date. A number of other buildings will be erected and the present structures improved to accommodate the new industry. The equipment installation will provide for the manufacture of steel billets, bars, black and galvanized sheets and kindred products. A new blast furnace is also projected. The company has been operating at Newport, and it is said that the change is being considered owing to the continuance of labor troubles. Articles of incorporation were filed recently under Delaware laws with a capital of $750,000, headed by W. N. and Joseph B. Andrews, Newport, now operating the Kentucky Rolling Mills in that city.

The Union Iron Works, Fifteenth and Cascade Streets, Erie, Pa., is planning for the rebuilding of the portion of its plant destroyed by fire on March 23, with loss estimated at close to $350,000, including buildings and equipment.

The Northwestern Steel & Iron Works, Eau Claire, Wis., is planning for the early rebuilding of the portion of its plant recently destroyed by fire, with loss approximating $150,000, including machinery.

The Danville Iron & Steel Company, Danville, Pa., has tentative plans under consideration for the erection of an addition to its plant for increased capacity. The structure will be one-story and it is proposed to break ground during the spring.

The Eastern Malleable Iron Co., Naugatuck, Conn., is planning for the erection of a new plant building at Watervliet, N. Y., consisting of a one-story building, 50 x 250 feet, estimated to cost in excess of $30,000. The company will also erect a new power plant at the works.

The Northwestern Iron Works, Devils Lake, N. D., has preliminary plans under consideration for the erection of an addition to its plant for increased production, to consist of a main two-story building, with subsidiary structures. It is said that the extension will cost close to $55,000.

PRODUCTION TOPICS

THE PURCHASE OF REFRACTORIES*

**By W. A. HULL, Chief, Refractories Section,
Bureau of Standards, Washington, D. C.**

The Government has gone in for business methods, and one of the things that is getting a beneficial shaking up is the system of purchasing. Now it so happens that there is, in the Federal Government, a Department of Commerce. There are several classes of people in the United States, including many of our important manufacturers, who are not as keenly or as constantly aware of the existence of the Department of Commerce as of one or two of the other Departments. Some of them doubtless think of the Department of Commerce simply as the Department of which Mr. Hoover is Secretary. Well, that is not a bad introduction to it, in case one has never made its acquaintance before. Not only is Mr. Hoover Secretary but the whole Department knows he is Secretary and has known it for some time. He has taken the secret out of secretary and given the Department a dynamic form of government. That is a mighty good thing, for the Department of Commerce is naturally called on for full steam ahead.

It was entirely logical and natural that the Bureau of the Budget, in taking up the problem of systemizing the Federal purchases, should find some things lacking in the matter of specifications. This led to the creation, by executive order, of a Federal Specifications Board, with Dr. Stratton, Director of the Bureau of Standards, as Chairman. Now the matter of specifications was by no means new to the Bureau of Standards, or to Director Stratton or to Mr. Hoover. In fact Mr. Hoover had made a most impressive demonstration of what could be done with specifications—of the right kind and used in the right way. In making wartime purchases of clothing, blankets and provisions for use in the Belgian Relief work, he had been amazed at the extremely reasonable prices at which goods of excellent quality could be obtained by the purchase of a large quantity of a single article to be made to a simple, definite specification. Now to make a specification, it is necessary to have standards of quality. Mr. Hoover found the Bureau of Standards working on standards of quality and he gave the signal to step on the gas.

And this is merely a bit of current history to make it clear why the Bureau of Standards is interested in the purchase of refractories.

The guiding star in all the research work on standards of quality and in the preparation of specifications is the elimination of waste. Standards of quality tend to prevent uncertainty and confusion. They tend to prevent the purchase of high priced things where low priced things would do as well; they tend to prevent the use of low priced things where high priced things are required and would be an economy; and sometimes they prevent buying the high priced thing when there is a better quality to be had at a lower price. This last occurrence is not at all unusual—not nearly as uncommon as it should be.

At the Bureau of Standards we receive requests from consumers for specifications for all sorts of things. Those who make these requests want something that will insure their getting good goods. They cannot be guided entirely by the price of these things nor by what the advertisements say about them. In some cases it is extremely difficult to judge of relative values by performance in service. Take paints, for example, and lubricating oils; you manufacturers know how hard it is to tell what you are getting for your money in things like this. The same is true, though to a less extent, in the purchase of dishes. Large purchasers of hotel china are keenly interested in standard tests for tableware and the Bureau is supplying them. Until these tests were put in use we did not know that we were making better hotel china at home than we were importing from Germany, England and even from France. Now that we are testing dishes, we can say that when specifications for this class of goods go into effect, the foreign producers will have something to worry about besides the tariff.

A number of the Governmental Departments are considerable users of refractories and one of the things that the Federal Specifications Board has taken up is specifications for refractories. A survey of the situation brought out the fact that the purchasing methods of the various Departments were not at all the same. One Department was buying on specifications and another was not and the specifications of one Department were not similar to those of another. As a result of this condition, the Bureau of Standards was asked to draft specification for the types of refractories that are purchased by the Government Departments.

Now the less one knows about refractories, the easier it is to write specifications. Perhaps it would be better to say that in order to make a good job of it, it is necessary to have a large amount of information and at the same time a reasonable allowance of common sense. Now at the Bureau of Standards we may have common sense enough for a job like this—anyhow we had sense enough to know that we didn't have anywhere near enough information; so we sent for more. As a result, some of the best equipped men in the United States, from both the producing and a number of consuming industries have responded to the invitation to join forces and work this thing out together. Two of these conferences have been held. At the first, the whole subject of tests was discussed, up one side and down the other. Everyone's opinion on every standard or near standard test was brought out. The effect was that of clearing the decks for action. In the second conference, a complete set of requirements for fire brick for coal fired boilers was drawn up. Of course there are special conditions encountered in the use of different kinds of coal in different types of boiler furnaces and it would be impossible for any group of men to draw up in one day specifications for all the special qualities of refractories that would be best suited to meet them. We thought we had done a day's work when we had expressed, in terms of simple test reuirements, what we would consider a satisfactory grade of brick to take care of the common run of modern, high duty, coal fired boiler service, but we put in a little overtime and wrote up the requirements for the clay.

Of course these requirements have not been decided on in anything like a final way but we have a conviction that that day's work is a milestone in the progress of the refractories industry for this is the first instance that we know of where American producers and consumers have joined forces and drafted even a tentative set of specifications for refractories for a specific service. It may be that it is only now that the industries are ready for such a thing.

(To be continued next month)

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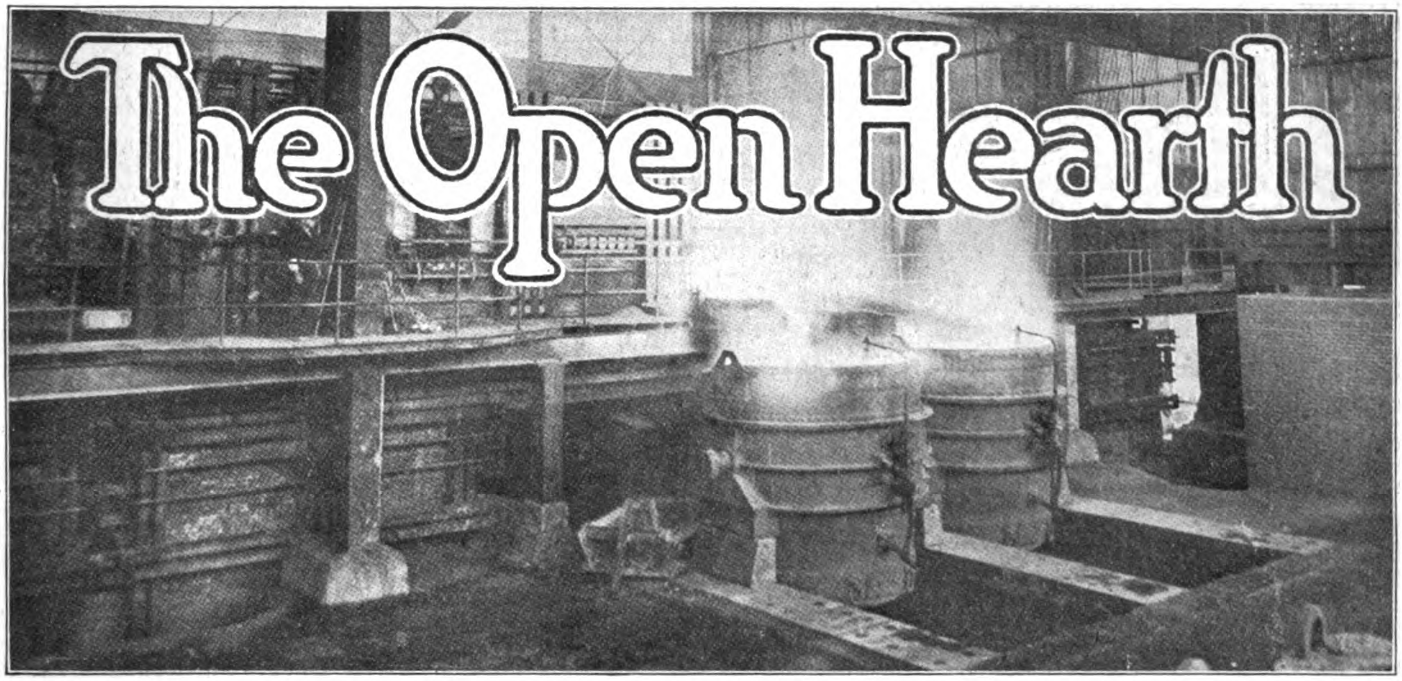
The Open Hearth



Bracken Todd, assistant superintendent of the blooming mills at the Monessen plant of the Pittsburgh Steel Company, has resigned his position to become superintendent of the rolling mills of the Andrews Steel Company at Newport, Ky. Mr. Todd has been associated with the Pittsburgh Steel Company for the past nine years.

Bracken Todd

At his departure from Monessen Mr. Todd was presented by the blooming mill employes with a gold watch and chain. Mr. Todd assumed charge of the rolling mills at Newport on April 15.

√ √

A. P. Blackstead, formerly chief engineer of the Camden Iron Works (R. D. Wood & Co.), Camden, N. J., and prior to that hydraulic engineer with the Henry R. Worthington Company, New York, has joined the engineering staff of the Dayton-Dowd Company, manufacturers of centrifugal pumps and approved underwriters' fire pumps. Mr. Blackstead has recently returned from Europe where he spent six months studying conditions and investigating recent developments in hydraulic engineering.

√ √

Howard K. Moore, secretary of the Portsmouth-Solvay Coke Company prior to its joint absorption by the Wheeling Steel Corporation and the American Rolling Mill Company, has been appointed assistant general manager of the Steubenville, Ohio, works, Wheeling Steel Corporation. Mr. Moore was assistant to Andrew Glass, president of the Whitaker-Glessner Company at Portsmouth, Ohio, for a number of years and previously had steel works experience in the eastern plants. Mr. Moore is a brother of G. W. Moore, general superintendent, Portsmouth, Ohio, works of the company.

√ √

Wm. H. Weichsel has resigned as manager of the Dover Works, the American Sheet & Tin Plate Company, Dover, Ohio, to become manager of the sheet mills of the Inland Steel Company, Indiana Harbor, Ind., effective April 1. W. H. Ashbaugh, Leechburg, Pa., has been appointed to succeed him. Mr. Weichsel has been in the steel business for 19 years, having started with the Aetna Standard works at Bridgeport, Ohio. For the past six years he has been at Dover, first as superintendent and for the past year as manager.

√ √

Henry F. Favor, superintendent, Crompton & Knowles Loom Works, Providence, R. I., sailed March 16 from Vancouver, B. C., for China and Japan on a business trip.

√ √

S. W. Tarr has been made chief engineer of the Oliver Iron Mining Company, succeeding the late Alexander M. Gow. Mr. Tarr was formerly superintendent of construction in the mechanical division of the company.

√ √

Fred Heiser has been made foundry superintendent of the malleable department of the Superior Steel Casting Company, Benton Harbor, Mich. Mr. Heiser formerly had charge of the malleable foundry of the Timken Detroit Axle Company, Canton, Ohio.

√ √

Wiley H. Marble, formerly manager of the American Stainless Steel Company, Pittsburgh, is now affiliated with the Palmer Engineering Company, 335 Fifth Avenue, that city. This company designs stokers, etc.

√ √

Ernest McKay has resigned his position as works superintendent of the Nova Scotia Steel & Coal Company to go to Pittsburgh, where he will engage in the steel industry.

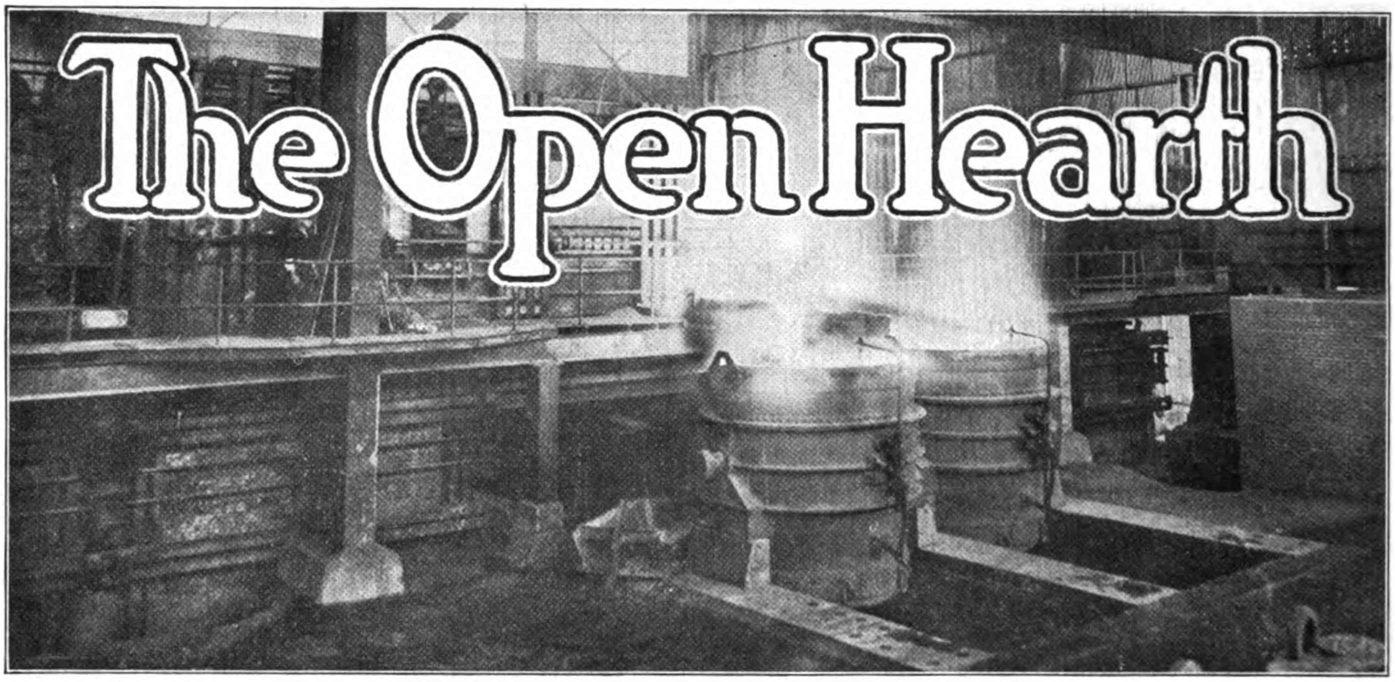
√ √

Baltzar De Mare, metallurgist and more recently steel superintendent for the Midvale Steel & Ordnance Company for approximately 20 years, now has been appointed general manager of the Union Electric Steel Company, Carnegie, Pa.

√ √

Robert Gregg, secretary and treasurer of the Atlantic Steel Company, Atlanta, has been elected president of the company, succeeding Thomas K. Glenn, who has been made chairman of the board of directors. Mr. Gregg is one of the country's youngest steel presidents, being only 37 years old. He was born in Atlanta, April 14, 1885; was educated in the public and preparatory schools there and was graduated from Georgia School of Technology as a Bachelor of Science in 1905, and next year completed a post-graduate course at Cornell with the degree of Mechanical Engineer. In August that year he entered

The Open Hearth



the employ of the Atlantic Steel Company as a clerk in the general superintendent's office. A year later he was transferred to the open hearth department, serving as a helper on furnaces. Then he was made a cost accountant and in 1909 was placed in charge of the accounting department and in 1912 was made secretary of the company in which he also is a director. Later he was made treasurer. Besides membership in several local organizations, Mr. Gregg is a member of the American Iron and Steel Institute.

V V

Nelson J. Darling, assistant general manager of the Erie, Pa., works of the General Electric Company, has been elected manager of the River Works, Lynn, Mass., of the company, to succeed Richard P. Cox, who has been acting manager of the West Lynn, Mass., works, but recently promoted to manager.

V V

William J. Priestly, formerly steel superintendent, naval ordnance plant, South Charleston, W. Va., has been appointed works manager, Pittsburgh Crucible Steel Company, Midland, Pa., succeeding H. P. Barnard, resigned, and has assumed his new duties. Prior to going to the naval ordnance plant, Mr. Priestley was a division superintendent at the Lehigh plant of the Bethlehem Steel Company. He was graduated from Lehigh University, class of 1908.

V V

L. A. Touzalin, assistant superintendent, blast furnaces, South Works, Illinois Steel Company, Chicago, has been appointed superintendent of blast furnaces at Joliet Works, Joliet, Ill. Harry Strain succeeds Mr. Touzalin at South Works.

V V

Lane Johnson has assumed his duties as chief engineer of the United Engineering & Foundry Company, Pittsburgh, having been previously engaged in consulting engineering work in the Pittsburgh district. He is a graduate of the Massachusetts Institute of Technology and has a broad experience in mill work. Among the firms with which he has been connected are the Colorado Fuel & Iron Company, Kokomo Steel & Wire Company, American Rolling Mill Company and Alex Laughlin.

V V

C. E. Potts, superintendent of the sheet mills of the Inland Steel Company, Indiana Harbor, Ind., has resigned, effective April 1, on account of ill health, and will make his home in Los Angeles, Cal. Mr. Potts is succeeded by William H. Weichsel, formerly superintendent of the Dover mill of the American Sheet & Tin Plate Company, New Philadelphia, Ohio.

V V

Walter J. Muncaster, vice president and general manager of the Cumberland Steel Company, Cumberland, Md., has resigned, after having held the position for 30 years. He was one of the organizers of the company for the manufacture of ground shafting, under patents granted to him.

V V

F. G. Peterson has resigned his position as foundry superintendent for the Bucyrus Company, South Milwaukee, Wis.

V V

C. J. McGregor, who for the past five years has been assistant sales agent in the Cleveland district of the American Steel & Wire Company, has been made sales agent for the company in the Buffalo district, effective April 1. Mr. McGregor has been with the American Steel & Wire Company over 20 years, always in a sales capacity, and had been stationed at Chicago and Worcester prior to coming to Cleveland. He succeeds at Buffalo, E. A. Niven, who is being transferred to the sales organization of the company at New York. The position of assistant sales agent at Cleveland will be filled by P. B. Gilroy, now attached to the Detroit office of the company.

V V

W. C. Peterson has resigned as metallurgical engineer for the Atlas Crucible Steel Company to become manager of the Alloy Steel Division of the Electric Alloy Steel Company, Youngstown, Ohio. Mr. Peterson for 12 years prior to his Atlas Crucible Steel Company connection was supervisor of materials in charge of metallurgical laboratories, heat treating departments, etc., of the Packard Motor Car Company.

V V

Guy Weir, assistant superintendent, Eliza Furnaces, Jones & Laughlin Steel Company, has resigned to accept the position of superintendent of blast furnaces for the Pittsburgh Crucible Steel Company, Midland, Pa. Mr. Weir, who has been with the Jones & Laughlin Steel Company for the past ten years, succeeds Harry H. Hodgett, resigned.

V V

Edward T. McNulty has resigned his position as superintendent of the Wheeling Steel Corporation's Yorkville, Ohio, plant to become general manager of the Charcoal Iron Products Co.

Some Pointers on By-Product Coke Oven Operations

THE KOPPERS COMPANY DEVELOPS NEW BY-PRODUCT COKE OVEN.

Announcement has been made by The Koppers Company of the development of a new type of by-product coke oven which promises to revolutionize by-product coke oven practice in this country. The design of this oven was developed by Joseph Becker, Consulting Engineer of The Koppers Company, and is covered by patents by The Koppers Company. A battery of these ovens has been in continuous operation at the plant of the Chicago By-Product Coke Company since the latter part of January. The average coking time has been under 11 hours and on tests this oven has carbonized coal in 9½ hours.

Since beginning operation these new Koppers ovens have been inspected by representatives of many of the large steel companies, all of whom have been most enthusiastic in their praise of this new design. In the judgment of one prominent coke oven man who was interviewed, this new oven will prove to be the most efficent by-product coke oven ever developed.

The outstanding feature of this new Koppers oven is the perfect heat control obtained, which insures a coke that is ideal for metallurgical purposes. Blast furnace operators who have examined this oven and the coke produced have stated that it is their belief that the use of coke made in this type of oven will make possible much more efficient blast furnace operation. Tests have been made with these ovens on many different grades of coal, including the straight high volatile coals from Pennsylvania and Kentucky, and Illinois coal, with excellent results.

In this connection it is pointed out by The Koppers Company that there is nothing new in making coke from Illinois coal. This has been done for a number of years in Koppers ovens; in fact in 1917 the Bureau of Standards conducted a test at the Koppers Plant of the Minnesota By-Product Coke Company, St. Paul, Minnesota, and the results obtained conclusively proved that a satisfactory grade of metallurgical coke could be made in the standard Koppers oven from Illinois coal. Other Koppers plants in the middle west district have also used Illinois coal with equally good results.

The perfection of this new Koppers oven is the consummation of many years' study and research work which The Koppers Company has devoted to the improvement of by-product coke oven practice in this country and is a striking example of the value of such a company to industry as a whole. In the opinion of the coke oven superintendents and blast furnace men who have inspected this new type of oven, its successful operation and the excellent results obtained mark the greatest stride in this industry in many years.

No detailed description of the design of this oven has been given out by The Koppers Company as yet, but it is expected that this will be made public in the near future. In an interview H. B. Rust, President of The Koppers Company stated that in his judgment this new oven will meet with such universal favor in the industry that it was very doubtful if The Koppers Company would ever build another oven of its old design.

THE CLAUDE PROCESS FOR PRODUCING SYNTHETIC AMMONIA.

A comprehensive description of the process and plant was given in a paper read by Mr. J. H. West, before a joint meeting of the Society of Chemical Industry, and the Institution of Mechanical Engineers.

The process consists of the direct combination of hydrogen and nitrogen under pressure, in the presence of a catalyst, the essential difference between this and the Haber process, being the 200 atmospheres in the latter case, against the 900 atmospheres in the former. There are many advantages to be derived from the Claude process, however. At any given temperature, the proportion of hydrogen and nitrogen remaining combined under conditions of equilibrium, increases rapidly with increase of pressure. Another point of importance with high pressure, is the very small pipes required; furthermore, a practical advantage is the heat produced with 900 atmospheres, whereby small catalyst vessels, heated externally and electrically, may be employed.

Interesting particulars are given of the super-compressor machine, a remarkable feature of which is its simplicity. Comparisons are also made between the time to heat up after a stoppage; against the three days of the Haber plant, 4-5 hours suffice with the Claude.

Carbon monoxide, which is liable to be present in hydrogen obtained from water gas or coke-oven gas, is eliminated by the Claude process, and this, together with suitable methods for obtaining the hydrogen and nitrogen, is described.

A further advantage of the high pressure, is the simple method of collecting ammonia in liquid form by merely cooling the gas to atmospheric temperature.

In conclusion, interesting comparative figures are given of the cost of power required for producing one ton of ammonia from coke-oven gas and from electrolytic hydrogen.

ORIGIN AND CHEMISTRY OF COALS AND SHALES.

An extensive investigation is being conducted by the Bureau of Mines regarding the origin, composition and chemistry of coals, cannel coals, and boghead coals. The coals from various beds and localities are examined microscopically. Thin sections are cut and examined at all magnifications; the constituents forming coal are examined and certain characters are recorded photographically. Coals may thus be studied concerning their nature, quality and various characteristics. The kinds, relative amounts and nature of the various constituents are studied and correlated with their distillation products and other qualities and characteristics shown in relation to their economic uses, such as coking, gas production, steaming, etc. Oil shales and cannel slates are also being studied by the Bureau of Mines as to their origin, composition and chemistry. Thin sections are cut and studied under the microscope and characters recorded photographically. The mineral matter is removed by means of acids and the remaining organic matter examined and compared with thin sections. The organic matter is burned out at low temperatures and the remaining mineral matter also examined and compared with thin sections. The kinds, nature and relative amounts of the various constituents are thus studied and correlated with the kinds, nature and relative amounts of distillation products.

TRADE PUBLICATIONS

The Uehling Instrument Company, Paterson, N. J., have published a new bulletin No. 112, covering Uehling CO_2 recording equipment, for guiding operating boiler plant engineers in the reduction of the waste of fuel up the chimney. Particular attention is called to the company's recently developed "Pyro-porus" filter which is used to keep the gas sampling lines clean.

The Deschanel Engineering Corporation, New York, N. Y., in an 8-page booklet illustrates and describes the Deschanel cableway, hoists and buckets.

The Kay Mfg. Company, Norwalk, Conn., calls attention to its new bulletin entitled "Whitney Free Floating Coupling," which is designed to transmit power from one shaft to another, though the shafts are not in alignment, without causing strains in the shafts or bearings. Disassembled couplings are shown, dimensions are given and also a price list.

The Oliver-Sherwood Company, San Francisco, Cal., a subsidiary of the Oliver Continuous Filter Company, has issued a new catalog on "Cutless Bearings." Illustrations are given as well as a description of the weak link in every pump, the secret of cutless bearing, the elimination of expense of machining, the many uses of cutless bearings and a list of pump manufacturers using the bearings.

The Norton Company, Worcester, Mass., in a 40-page booklet, illustrates and describes "Alundum Safety Tile," which is for stair treads, floors, ramps, elevator landings, entrances to public buildings or wherever a slip-proof, non-wearing surface is desired. Illustrations and descriptions are given on materials and process of manufacture, its advantages, general characteristic of physical properties, types and sizes and specifications for the proper installation of alundum safety tile. Interesting illustrations are given of the actual use of this tile in buildings, subways, stairs, floors, etc.

The Fulton Foundry & Machine Company, Cleveland, Ohio, describes the Airedale clutch in a bulletin just issuel. This clutch is made for services from 6 to 660 hp. in standard sizes, and is applicable for a wide range of machines in many kinds of industries. The clutch will not "grab," but picks up gently and is simple and ruggedly made.

The Merrill Company, San Francisco, Cal., announces it snew catalog. "Merco Processes and Products." Descriptions are given of the Merco precipitation processes and products and also some of the up-to-date results achieved by representative installations, as well as descriptions of the Crowe vacuum-zinc shavings process, Merrill sluicing clarifying filter, Merco-Nordstrom plug valve, Merrillite and Merco methods for clarifying and precipitating cyanide solutions.

The Philadelphia Drying Machinery Company, Philadelphia, Pa., has recently issued a 4-page folder which describes the various types of "Hurricane" driers for chemicals, battery plates, pharmaceuticals, electrical porcelain, leather, tobacco, spark plugs, food products, etc. The truck tray drier is described as well as the storage battery late drier, the tunnel truck driers, automatic conveyor type of drier, cabinet tray drier, continuous sectional conveyor drier and "Hurricane" automatic combination stick and apron tobacco drier.

The Wellman-Seaver-Morgan Company, Cleveland, Ohio, has issued Bulletin 71 descriptive of the application of labor-saving machinery, particularly car dumpers, excavators, filling bridges and excavating bridges. It also describes the practical method of working very low grade ore, especially by the leaching process.

The Colorado Iron Works Company has issued Pamphlet 33, on "The Akins Flotation and Aeration Machine."

The American Steam Gauge & Valve Mfg. Company of Boston, Mass., is distributing a folder describing its recording thermometer which has recently made its appearance on the market. This new product is actuated by different methods, depending on the purpose, and either saturated vapor expansion, inert gas or liquid is employed. It is in a 10-in. moisture-proof case to record any temperature up to 1,000 deg. F. at any distance up to 200 ft.

The Uehling Instrument Company, Paterson, N. J., announces two new publications: Bulletin 220, on "Magnitude of the Power Plant's Chimney Loss," and Bulletin 221, on "Relation Between CO_2 and Money Wasted Up the Chimney."

TRADE NOTES

The Freeport Sulphur Company, New York and Freeport, Texas, awarded contract on March 2 to Dwight P. Robinson & Company for the design and construction of a complete sulphur mining plant at Hoskins Mound, Texas. Cloyd M. Chapman has been retained by the Freeport Sulphur Company as consulting engineer.

Freyn, Brassert & Company announce that the following officers have been named in their company: F. H. Willcox, vice president; Wyman Eaton, vice president; L. T. Shorley, secretary.

The Electric Furnace Company has moved its general and sales offices from Alliance, Ohio, to Salem, Ohio. By this action all departments of the company will be consolidated at its work, Wilson Street and Pennsylvania Railroad, Salem, Ohio.

The Sharon Pressed Steel Company have made the following appointments in their sales forces: W. C. Ames has been appointed district sales manager at 20 East Jackson Blvd., Chicago, Ill.; Ralph E. Phillips has been appointed district sales manager with headquarters at 66 Broadway, New York City.

Combustion Engineering Corporation announce the opening of a new branch office at 1137 Guardian Bldg., Cleveland, Ohio. The office will be in charge of Frank Henderson, a prominent stoker man.

Detroit Seamless Steel Tubes Company of Detroit, Mich., makers of cold drawn seamless boiler and mechanical tubing, have just established their own branch sales office in New York City. It is located in the Canadian Pacific Bldg., 342 Madison Ave., between Forty-third and Forty-fourth Sts. A noteworthy addition is the appointment of H. C. Kensing as district sales manager for the New York territory.

Freyn, Brassert & Company, Chicago, have been retained as consulting engineers by the Cranberry Furnace Company of Johnson City, Tenn.

The Chain Belt Company, Milwaukee, Wis., has announced the appointment of G. F. Sherratt as manager of the Pittsburgh office in the Union Arcade Bldg. The Ward Equipment Company of Pittsburgh will continue to handle the complete line of Rex concrete mixers and pavers, and the United Equipment Company the Rex traveling water screens.

The Treadwell Engineering Company, Easton, Pa., announce the affiliation of Mark L. James as second vice president.

COMING MEETINGS

May 15-20—National Association of Purchasing Agents, seventh annual convention, also exposition at Exposition Park, Rochester, N. Y. H. R. Heydon, 19 Park Place, New York, is secretary.

May 25-26—American Society for Steel Treating, Sectional Meeting, Bureau of Mines Auditorium, Pittsburgh, Pa. D. W. McDowell, Jones & Laughlin Steel Company, local secretary.

June 5-9—American Foundrymen's Association annual convention and exhibition at Exposition Park, Rochester, N. Y. C. E. Hoyt, Marquette Bldg., 140 South Dearborn Street, Chicago, is secretary.

June 26-July 1—American Society for Testing Materials ,twenty-fifth annual meeting, Chalfonte-Hadden Hall Hotel, Atlantic City, N. J. C. L. Warwick, 1315 Spruce Street, Philadelphia, is secretary.

September 11-15—Association of Iron and Steel Electrical Engineers, 1922 convention at the new auditorium, Cleveland. John F. Kelly, Empire Bldg., Pittsburgh, is secretary.

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